COMPUTER-INTEGRATED MANUFACTURING: A STEP AT A TIME

HIGH TECHNOLOGY

FEBRUARY 1987 THE MAGAZINE FOR TECHNOLOGY MANAGEMENT PRICE $3.00

PARALLEL PROCESSING
COMPETITION HEATS UP

COMMERCIAL AIRCRAFT: THE NEXT GENERATION

ENERGY-WISE BUILDINGS

Randall Rettberg and Paul Castleman
of BBN Advanced Computers Inc.

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Coordination unlocks
If you're like many manufacturers, you automate work centers one at a time, as the need arises.
Your goal is productivity. And, potentially, such "islands of automation" are the answer. But if you can't control the work flow between them, they may never achieve their promise.
For efficient and flexible production in small lot sizes, the work pieces, work orders, parts programs and tooling must all arrive together. And that demands data which must be collected from every point in the enterprise and then made available in a useful form.
To make that happen, you need Computer Integrated Manufacturing (CIM)—the use of the computer to coordinate activities from market forecasting and engineering through production and distribution.
IBM offers special resources to meet the CIM challenge: Host computers that work easily with other computers. Communication architec-

EAST KILBRIDE, DEEP IN THE HEART OF SCOTLAND'S SILICON GLEN HAS ATTRACTED MORE U.S. INVESTMENT THAN ANY OTHER SCOTTISH LOCATION. SO SUCCESSFUL ARE THE U.S. COMPANIES ALREADY HERE THEY NOW EMPLOY NO LESS THAN 20% OF THE TOWN'S TOTAL WORKFORCE, EARNING MILLIONS OF DOLLARS EVERY YEAR.

In 1959, Kraft Foods became the first U.S. company to choose East Kilbride as an overseas location.

Since then, the town has continued to attract more and more companies from the States.

East Kilbride sits in the very heart of Scotland's Silicon Glen.

Within a 50 mile radius there are over 200 electronics companies forming not only a close-knit nucleus of suppliers, but a considerable market too.

As well as being the ideal gateway to the expanding markets in the U.K., East Kilbride is also well positioned for companies wishing to exploit the vast European markets.

Using East Kilbride as a tariff-free springboard, your company has another 600 million potential European customers.

Our labour record is excellent, with 95% of facilities enjoying a strike-free period of five years.

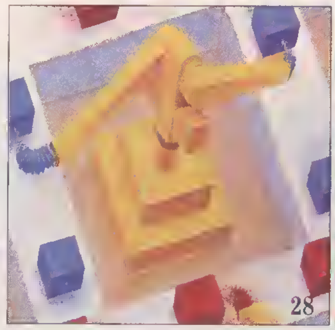
Because 80% of companies are union free, East Kilbride's position as a right to work town is further consolidated.

The town has a proven track record in successfully catering for industrial investment and our range of financial incentives is among the best offered by any area in the U.K.

If your company is considering an offshore project, contact Rick Packer on (617) 431 7474 at PRTM, 36 Washington Street, Wellesley Hills, Massachusetts 02181.

And join the other U.S. companies currently flying the flag in East Kilbride.

FEBRUARY 1987 HIGH TECHNOLOGY VOL. 7, NO. 2



FEATURES

DEPARTMENTS

Cover Randall Rettberg, VP of Research and Engineering, and Paul Castleman, President/CEO, BBN Advanced Computers (Cambridge, Mass.). Photo by Bill Huber; inset by Imagebuilders Design

NEW 32-BIT CMOS MICROPROCESSORS.

The two new members of NEC's CMOS microprocessor V-Series bring unprecedented density and performance in the 32-bit realm. The V60 and V70 supermicros are the first to integrate a Memory Management Unit and basic floating-point processing functions on a single chip.

The V60 has a 16-bit external data bus for an easy, affordable path into 32-bit products while the V70 is a full 32-bit engine designed to power leading-edge systems.

The super-fast V60 and V70 offer a clock speed of 16MHz, and execute 3.5 MIPS and 6 MIPS respectively. A six-stage pipelined CPU enables concurrent execution of up to 4 instructions. With 32 on-board 32-bit general-purpose registers, there is no need to access slow off-chip memory.

The V60/V70 feature an on-chip memory management unit with 4 gigabytes of demand-paged virtual memory space, and 4 levels of memory protection for multi-tasking and multi-user environments.

The V60/V70 instruction set is ideal for high-level languages and OS support (UNIX™ V and proprietary realtime OS). There are 21 addressing modes, 273 instructions, and an emulation mode for 16-bit V20/V30 software.

UNIX: trademark of AT&T Bell Laboratories.

NUMBER 136

COMING SOON: 1.3/1.55μ DFB LASER DIODES.

Dispersion has always been a major obstacle in long-distance, high-speed lightwave communications. With conventional laser diodes emitting multiple spectrums, pulses deteriorate by dispersion after long travel through the fiber. This in turn limits repeater span to 20–30km and capacity to 400–560Mbps for the prevalent 1.3μ fiber optic systems.

NEC has overcome this obstacle with newly-developed distributed feedback (DFB) laser diodes for 1.3μ and 1.55μ fiber optic transmission systems. They feature a stable single longitudinal mode operation, high efficiency and high output power. The new DFB laser diodes are expected to expand repeater span to 80–100km for 1.3μ system or 100–200km for 1.55μ system.

NEC's new DFB laser diodes inherit the renowned double channel planar-buried heterostructure (DC-PBH) and have a diffraction grating in the optical guide region to produce a single wavelength. Output powers are rated 8mw for the 1.3μ NDL5600 and 5mw for the 1.55μ NDL5650. They come in the TO-5 package with an integral monitor photo diode or chip-on-carrier configurations.

As matching light-receiving devices, NEC has planar type InGaAs avalanche photo diodes. They have a selective guard ring construction to achieve high sensitivity and excellent reliability.

NEW INTELLIGENT BUILDING COMPLEX AT VANCOUVER.

The intelligent building is an idea whose time has come. As the perfect nestling for office workers in the Information Age, it centers on an advanced information management system which provides simultaneous voice, data and image services to tenants at less cost while it controls the entire building environment efficiently.

The World Trade Centre/Pan-Pacific Vancouver Hotel recently opened is just such an installation. NEC's NEAX 2400 Information Management System (IMS) allows tenants to utilize enhanced telephone/facsimile services including least-cost routing, message center and voice mail services, and computer terminal connection via a multifunction digital telephone set. The NEAX 2400 IMS also offers sophisticated services to hotel guests.

NEC's Intelligent Building Systems, based on our unique C&C (integrated computer and communications) technology, are the most advanced and comprehensive available today. As the core of this system, the modular NEAX 2400 IMS can expand to 255 tenant partitions. It supports more than a hundred advanced features including a protocol converter to allow communication with most popular host computers.

NEC also supplies comprehensive component equipment including multifunction digital telephones, information display pagers, high-speed facsimiles, business and personal computers, teleconferencing and CATV equipment and local distribution microwave links.

NEC's comprehensive systems breathe new life into the smart building concept, bringing costly services like teleconferencing within the reach of every business.

NEW HIGH-CAPACITY 64QAM DMR SERIES.

NEC's newest 800 Series high-capacity digital microwave radio (DMR) systems transmit two or three DS3 signals per RF carrier, utilizing 64-state quadrature amplitude modulation (64QAM) for effective use of radio spectrum.

Three systems meeting FCC standards are available: a 4GHz 90M-bit system providing 1,344 voice channels, and 6GHz and 11GHz 135M-bit systems for 2,016 voice channels.

The new systems incorporate the latest LSIs, hybrid and microwave ICs throughout to achieve compact design, lower power consumption and improved system reliability. Housed in a standard 19-inch rack, they require minimal cabling work for installation.

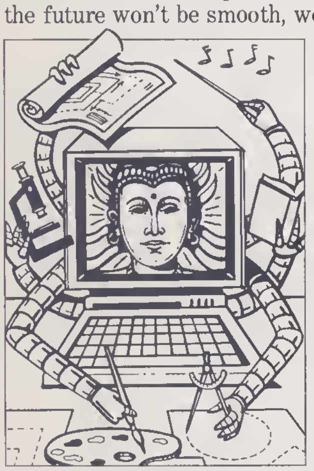
The advanced 800 Series is fully compatible with Bell's facility maintenance and administration system.

NEC

OPINION

NEW DIRECTIONS FOR PERSONAL PRODUCTIVITY TOOLS

Is that new era of desktop automation finally dawning? Will the white-collar workplace really be transformed this time? So many promises in this field have resulted in disappointment, it's easy to conclude that current predictions of revolutionary changes are merely a new round of hype and vaporware. But there is substance behind the promise this time, and even though the road to the future won't be smooth, we should soon see personal productivity tools far beyond what we've seen in the past.



Key to these advances is a new round of 32-bit microprocessors (particularly Intel's 80386 and Motorola's 68020). Coupled with an array of coprocessors, mainly for graphics and other well-defined tasks like array processing or fourier transforms, these microchips will greatly speed the response of desktop computers.

Dynamic memory chips have reached the million-bit level, and 4-megabit designs were described at the Electron Devices Meeting in December (more will be revealed at this month's Solid State Circuits Conference in New York). Software capabilities are pushing ahead, too. Fourth-generation languages improve the computer interface, and integrated software makes it possible to link work in reports, charts, and spreadsheets, as well as to move smoothly between tasks. Workstation networks are taking shape with gateways and software to connect otherwise incompatible equipment. Some computers can now run software written for different operating systems. Optical discs will enable ready access to organized information in greater-than-encyclopedic lengths.

A major complaint about this field in the past has been that buyers don't particularly care what's in the box; it's what it can do that counts. So what will all these technical advances mean?

The new systems will handle complex tasks faster and more efficiently. So far, most micros have served single users. But new ones will allow work groups to handle projects cooperatively—to share files, graphics, data, and ideas.

We will think of these tools as something far different from the old concept of a "computer." Although some tasks will require computation, these systems will be used for learning, planning, designing, communicating, and exploring new concepts. Their greatly increased storage and speed, and the ease of connecting them to other systems, should enable software developers to make the new systems far more flexible and interactive than ever before.

The new technological advances are like clay. They have the potential to achieve these things and much more—at affordable prices. But lots of ingenuity and hard work will be needed to mold them into a form that can make it all happen. We'll keep you posted on how well it's going.

Robert Haavind

Robert Haavind

BRAD HAMANN

HIGH TECHNOLOGY

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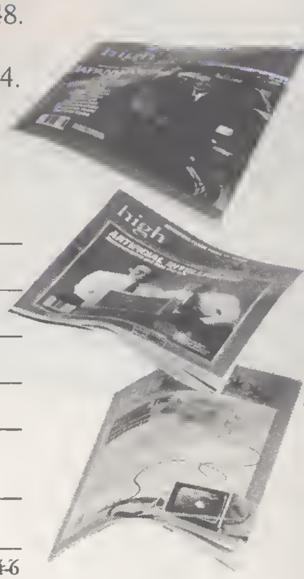

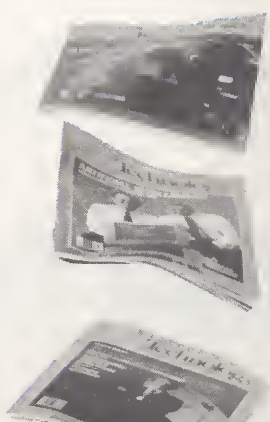

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LETTERS

Getting to the heart of Japanese R&D

In "Windows on Japan" (Aug. 1986, p. 12), Bruce Rubinger correctly points out the pressing need for U.S. companies to monitor Japanese R&D. He also performs a real service in demonstrating how a wide range of information on the Japanese electronics industry can be readily accessed in this country.

What needs to be added, however, is that these sources of information do not always reveal the state of the art in Japanese technology, nor do they necessarily provide the context needed to predict future trends. If businesses or other organizations seek to understand a technology's leading edge, they might consider several additional approaches.

From studies conducted at Battelle's Pacific Northwest Laboratories for the U.S. Department of Energy, we have found that scientific and technological advances in Japan are often first communicated by word of mouth within the Japanese research community. While this is also the case in the U.S., the practice in Japan is reinforced by the limitations of written Japanese—new characters, necessitated by new technical terms, are not efficient to produce or to initially interpret. For American researchers to stay abreast of Japanese developments, therefore, it is important to have direct contact with their Japanese counterparts, or at least with U.S. researchers who maintain close ties with colleagues in Japan.

As in the U.S., Japanese research will ultimately appear in a technical or commercial journal, but the time lag from discovery to publication may diminish its benefit to U.S. companies. Furthermore, few Japanese technical journals undergo rigorous peer review, so the "breakthrough" article may be buried by articles of lesser technical merit and thus hard to uncover. Japan's major journals are routinely entered into computer databases. But as in the U.S., Japanese databases lag article publication by perhaps 6–12 months.

It is important to note that titles and abstracts obtained from Japanese computer searches are wholly in Japanese. Translation of technical Japanese requires detailed knowledge of the specific subject area in order to decipher the highly specialized characters used. There is no complete dictionary of these characters, and even costly translation services can often be stumped. Fortunately, the major Japanese research journals often include English titles, abstracts, and graph titles, which are frequently all that is necessary for U.S. researchers.

LOU JONES

Toshiba is developing reusable software modules.

It is also important to recognize that many significant technical developments in Japan do not appear directly as experimental results or as business news. We have found, for example, that the power of the Ministry of International Trade and Industry (MITI) not only in controlling the nation's gas and electric utilites but also in directing research in areas like energy-efficient HVAC equipment is tremendous. There is no line item in MITI's budget or official report to indicate this, however. In a country like Japan, where industrial planning is indirect but omnipresent, it is important to be aware of such "soft" points of information.

Japan's approach to meeting technological and industrial needs is clearly different from our own. If we want to learn more about Japanese technology, we have to understand how Japan approaches technical development problems and what the cutting edge truly embodies. Thus technical journals and databases are helpful but only supplementary. Closer contact between our countries' specialists is the primary way to supply the necessary details and overall insights.

Robert Hutchinson
Chris Howard
Zachary Fisher
W. Bradford Ashton

Energy Systems Department
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Something didn't gel

"Computerizing gene analysis" (Dec. 1986, p. 46) was an excellent update on the quickly expanding field of DNA analysis. There was one error, however. You stated that after labeling the DNA fragments with isotopes, the fragments are sorted by gel electrophoresis on a rubbery gel compound called agarose. Determining DNA sequences is in fact done on polyacrylamide gels.

Agarose is generally used for the electrophoretic separation of large proteins and of a variety of large DNA fragments. However, the gel matrix formed by agarose is not fine enough to adequately determine the sequence of very small fragments. Polyacrylamide gel forms a much finer gel matrix, and thus is the choice for DNA sequencing.

Gerald A. Moss, General Manager
FMC BioProducts
[A leading manufacturer of agarose]
Philadelphia, Pa.

Two sculls are better than one

Edward Cooper's letter "Good idea, bad image" (Dec. 1986, p. 5) pointed out an error in your drawing of an eight-man shell in "Pulling together on computer communications (Sept. 1986, p. 30). I'm surprised you didn't realize that your artist had observed an octopod, or octopede, making its way up or down the Charles River. An octopod/pede is rowed by eight oarsmen, each of whom is pulling two sculls (oars) instead of one.

Robert W. Perkins
Newington, Conn.

In October Resources (p. 69), the listing for *Videodisc and Optical Disc Update* was out of date. It should have read: *Optical Information Systems Update*, Meckler Publishing Corp., 11 Ferry Lane West, Westport, CT 06880. $195/yr (biweekly).

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110. Or send to MCI Mailbox: HIGHTECHLET.

INNOVATIONS

China smiles on high tech ventures

In an effort to heat up its cooling climate for foreign investment, the People's Republic of China recently revamped regulations governing foreign-owned ventures and created a special, favored category for enterprises that use advanced technology or produce goods mainly for export from China. The new policies promise these businesses a previously unknown level of autonomy, allowing them, for example, to hire and fire employees, set wages, and use foreign—which could mean capitalist—methods of management. Such companies will also be able to trade local and foreign currency among themselves, helping ease problems caused by foreign exchange shortages.

In addition, high tech and export-oriented ventures will be eligible for significant tax breaks and reduced land-use and utility fees. They will also be given priority in obtaining loans and services such as installation of electricity.

The new rules indicate that the government is trying to address foreign-owned businesses' complaints about red tape and high overhead costs—problems that led last year to the first decline in the rate of foreign investment since the open-door policy began in 1978. While special treatment for export ventures is aimed at bringing more foreign currency to China, the favored status for high tech enterprises is part of the country's long-range effort to modernize its infrastructure.

Besides these nationwide incentives, high tech companies can benefit from a number of local programs. For example, Shanghai is establishing a zone for high tech businesses that will include special facilities for water, electricity, gas, and telecommunications, as well as its own housing units for foreign specialists, says Liu Zhen-Yuan, deputy mayor of Shanghai. The first phase of the project should be complete by 1990, he says, and the final stage by 1995. Investment by the city government is expected to total 100 million yuan (about $27 million).

Storing images on hard disks

Fields as diverse as radiology and security systems could benefit from a new analog image-storage system that is said to offer more flexibility than laser videodisc units and greater storage density than digital recording systems. The Telesis Video Image File, developed by Calco Digital Equipment (Scottsdale, Ariz.) and marketed by Telesis Distributing (Reno, Nev.), can record as many as 2460 black-and-white freeze-frame pictures on its own 20-megabyte magnetic hard disk. It accepts images from several sources, including VCRs, video cameras, and TV broadcasts. The system can be connected to most computers, allowing images to be indexed and recalled with software provided by the vendor or written by the user.

DANIEL FRIEDMAN

Gary Mayhak, president of Calco Digital, uses a microcomputer to call up video images stored on the Telesis system.

In order to cram as many images as possible onto a disk, the system uses a space-saving analog recording technique. In both analog and digital image storage, the brightness of every tiny picture element (pixel) is designated by magnetic marks on the disk. A digital system, such as a plug-in board that digitizes images on a PC screen, assigns each brightness value a number—say, 1 through 256, to allow 256 different shades—which is represented by a series of binary bits (*1*s and *0*s). These bits are then encoded on the disk as positively or negatively aligned magnetic marks. A system that discriminates 256 (2^8) shades must therefore make eight separate marks to indicate the brightness of a single pixel. In Calco's analog method there are also 256 shades, but each is indicated by a single mark. What counts is the mark's position within a tiny "cell" on the disk; a mark closer to one end of the cell or the other indicates a brighter or a darker pixel. Since one mark does the work of eight, this method takes up much less memory space.

The $2995 Video Image File can be used in a variety of applications—including identification systems, to allow a security guard to compare a person's face with a stored picture; training systems, to display, for example, images of equipment to be repaired; and medical record keeping, for storage of images such as CT scans. Calco claims that its product—unlike videodisc systems, which are read-only—allows images to be added or deleted easily, as well as recalled quickly (in no more than a fifth of a second, versus about half a second for a videodisc).

Hardening through blasting

Laser-triggered explosions can transform certain soft materials into much more valuable hard ones—such as graphite into industrial diamonds—according to researchers at KMS Fusion (Ann Arbor, Mich.). KMS surrounds a plug of starting material with a chemical explosive encased in a metal-coated plastic shell about a centimeter in diameter. Two infrared laser beams zap the spherical shell from opposite sides, setting off a symmetrical blast that subjects the material to pressures of about 15 million pounds per square inch. The process is a spinoff from KMS's continuing

efforts, sponsored by the Department of Energy, to ignite nuclear fusion reactions in hydrogen-filled pellets.

In initial demonstrations, the KMS system changed boron nitride from an inexpensive soft form into a highly abrasive ceramic crystal suitable for machining, grinding, and polishing. But not all the transformations involve hardness; the extreme physical shock can also break chemical bonds to expose more reaction sites, greatly multiplying the potency of chemical catalysts such as those used in oil refining.

So far, KMS has produced only a fraction of a gram of material at a time. Commercial production would require more lasers or larger shells.

High tech temps in growing demand

Say "temp" and most people will probably think of office help. But in high tech fields, the term is taking on a new meaning. Every day about 75,000 scientists, engineers, programmers, technical writers, and technicians report to work on a temporary basis, and the market is expanding rapidly: during the past three years, it has grown three- to fivefold annually, according to Bruce Culver, president of Lab Support (Woodland Hills, Cal.), one of several hundred companies that have sprung up across the nation to provide technical temps. The workers come with a wide range of training and experience, from lab technicians fresh out of college to veteran scientists with PhDs. Fees vary from as little as $15 to as much as $150 an hour.

Equally diverse are the tasks for which the temps are being hired. For example, clients of Lab Support's nationwide Rent-a-Chemist service include oil refineries, drug companies, and analytic chemistry labs; a chemist might be brought in to help clear up a backlog of lab tests or to advise the client in choosing equipment and techniques for a particular project. One area where Rent-a-Chemist temps are in great demand, says Culver, is in setting up safety programs and maintaining material safety data sheets required by the new federal right-to-know legislation.

Culver attributes the recent surge of in-

Lab Support president Bruce Culver (left) and VP Raf Dahlquist see big markets for technical temps.

terest in high tech temps to the uncertain economic climate. Many technology firms that need extra help are turning to temp agencies instead of hiring additional staff that may eventually have to be laid off. That way, says Culver, companies pay less unemployment insurance and avoid the morale problems that arise from frequent hirings and firings.

Compact discs get a stab from the past

The compact disc has become an emblem of sleek, elegant technology. But in an effort to relieve bottlenecks in CD production, one manufacturer has returned to an implement from the Stone Age of recorded sound: the needle. A major hang-up in producing CDs comes in generating the master disc from which the plastic replicas are pressed. At present, masters are fabricated in a semiconductor-style cleanroom by shining a laser beam (which carries the digital audio signal) onto a piece of glass covered with a photoresist, or light-sensitive coating. Developing and chemically etching the resist leaves the surface pockmarked with micron-size pits. The scarcity of these multimillion-dollar mastering facilities—there are only two in the U.S.—contributes to CDs' long lead times, high cost, and relatively limited selection.

Teldec, a large West German record company, replaces the photo-optical mastering process with a mechanical one. A diamond-tipped stylus driven by a piezoelectric element taps pits into a thin layer of copper that has been evaporated onto a glass disc. Such "direct metal mastering" requires no cleanroom; dust particles that would interfere with laser exposure are simply mashed into the copper by the needle. Teldec, which began using the technique for its own discs early this year, is marketing the equipment to record companies and to studios that specialize in making masters of records and tapes. Most such companies must now wait in line at the overburdened compact disc pressing plants to get their recordings turned into CD masters.

Trimming the fat from hydrogenation

Researchers at Tulane University in New Orleans have developed a more efficient way to hydrogenate, or add hydrogen atoms to, organic compounds. Hydrogenation is the process that turns vegetable oil into solid shortening, glucose into sorbitol (used in toothpaste and other products), and benzene into cyclohexane (used to make nylon).

In current commercial methods, gaseous hydrogen is forced into a reaction solution at temperatures of up to 200° C and pressures of up to 100 atmospheres; a metal catalyst in the solution then promotes the addition of the hydrogen to other molecules. Not only do such techniques consume a lot of energy, but much of the hydrogen either escapes from the solution before reaction or is taken up in the formation of unwanted byproducts.

In Tulane's method (partly developed at UCLA), hydrogen atoms are formed by passing electricity through water in the reaction solution and are adsorbed on a powdered-nickel catalyst, so they can't escape until they combine with the other reactants. Because gas need not be pumped into solution, says developer Peter N. Pintauro, assistant professor of chemical engineering, the process runs at only about 60° C and at atmospheric pressure. What's more, he says, very little hydrogen is lost. "In converting glucose to sorbitol, for example, standard electrochemical methods are only about 20% efficient. The new process comes very close to 100%."

INSIGHTS

TOMORROW'S WORKFORCE

PAT HILL HUBBARD, VICE-PRESIDENT
ENGINEERING EDUCATION AND MANAGEMENT PROGRAMS
AMERICAN ELECTRONICS ASSOCIATION

In an international economy that is increasingly knowledge-based, success depends less on a nation's natural resources than on its ability to parlay technological advances into efficient, high-quality production processes. Such manufacturing excellence is achieved primarily through a flexible and competent workforce.

But that workforce in the United States seems to be shrinking as fewer young people are pursuing high technology careers. In the last two years, the number of college freshmen intending to study engineering or computer science has dropped 50%.

Students who are planning to enter technological fields will find an increasing shortage of qualified educators. The number of high-school math teachers fell 78% between 1971 and 1980, and it is expected that by 1992 we will lose 35% of those we currently have. At the college level, present U.S. engineering faculty vacancies across the country now stand at 8.8%—22% in California—and these vacancies will increase over the next decade as the many science and engineering professors hired in the late '50s and early '60s in response to Sputnik retire.

Given these shortages, employers must look for new ways to secure the kinds of technical skills they need. Rather than continue to recruit "ready-to-wear" labor, companies will need to step up their internal efforts to retailor workers for new assignments. And when they do recruit, it will by necessity be more and more from nontraditional sources—women, minorities, and older workers.

But to attract and keep skilled, adaptable workers—no matter who they are—employers will also have to change some of their management policies. For instance, as more workers ask for benefit options rather than standardized benefit plans, more employers are providing them. Five times as many companies today offer flexible ("supermarket") benefit plans as three years ago.

Workers are also asking for flex-time options, and companies are beginning to respond. Most flex-time plans require people to be at work during peak business hours but allow a one- to two-hour leeway in starting and quitting times. Some com-

panies permit workers to alternate short workdays with long ones, while others have agreed to shorter workweeks, with employees taking commensurate pay cuts but generally retaining seniority and benefits. And a few enlightened companies offer sabbaticals for senior employees, knowing that distance often rekindles workers' enthusiasm.

Job sharing—of particular interest to

Rather than continue to recruit "ready-to-wear" labor, companies will increasingly retailor workers for new assignments.

working mothers with young children—is an option that most employers have so far resisted. They anticipate difficulty with follow-through from one worker to another; they are uneasy about differences in workers' abilities; and they are reluctant to incur the time and cost of increased supervision and double benefits.

Nevertheless, a growing number of workers, both men and women, want to spend more time at home. They prefer autonomy in managing their work time and cannot abide the stress and duration of long-distance commuting. Technology—specifically the combination of computer and telephone—now allows these people to telecommute, or work out of their homes. While only some 300 firms nationwide currently employ such cottage workers, many observers predict substantial growth over the next decade as the benefits of this option become apparent.

A more prevalent U.S. labor trend is the use of contract or temporary workers. This concept appeals to individuals who desire job and geographical mobility as well as increased leisure time. In June 1986, according to the U.S. Department of Labor, over 780,000 men and women were employed as contract workers—more than double the number for 1982—and DOL predicts these workers will number 10 million by 1996.

In the past, contract workers tended to be nonprofessionals, but they now include such people as computer programmers, engineers hired to do one- or two-year projects, and freelance consultants who troubleshoot as needed. Their working styles especially benefit employers facing tough and fluctuating economic constraints. Such employers can use contract workers to scale their workforce up or down without damaging permanent employees' morale, and to reduce recruitment, benefit, and severance costs.

It is fitting that the development and management of technology, which epitomizes change, should depend on a rapidly changing workforce. People now require more satisfaction from work than their parents did, but they also demand greater quality of life both on and off the job and therefore insist on a wider range of work options.

As a result, definitions of "stability" and "security" are changing radically. Workers of tomorrow are more likely to push for continuous retraining and education benefits that will increase job mobility than to opt for lifelong employment in one job and in one place. Companies are thus discovering that if they want workers who can adapt to new processes and skill requirements, new management practices must also be instituted. To remain globally competitive, we will need to better accommodate a diverse and changing workforce. □

AZDEL:

REINFORCING THE COMPOSITES MARKET

Last summer, General Electric and PPG formed Azdel (Shelby, N.C.), a joint venture aimed at developing a new family of thermoplastic composites for automotive, construction, and other applications. If markets for the composites unfold as the parent companies predict, annual growth rates for these materials could reach 20% by the end of the decade.

Thermoplastic composites—reinforcing glass fibers embedded in a matrix of low-cost plastic resin—are expected to be as durable as the metals they're intended to replace, and at least as tough as traditional thermoset composites (such as those based on epoxy). Although PPG has been marketing the materials under the name Azdel for several years—as battery trays and seat frames, for example—the collaboration could open several other markets by lending a new synergy to the operation. "PPG has lots of expertise in glass fibers, but not in resins," says Michael Brown, general manager of GE's technopolymers group in Pittsfield, Mass. "We have resins but no fibers. It's a good fit." (GE traditionally bought its fibers from outside suppliers.)

Some major differences exist between thermoplastics and thermosets. The former are generally lighter, as well as faster and easier to process. For the cost-conscious processor, however, the most important difference is recyclability; thermoplastics can be melted for reuse, but thermosets when melted degrade into useless, tarlike materials.

Thermoplastic composites have traditionally been sold as "prepregs"—fiber mats impregnated with a sticky, unpolymerized resin that must be stored under special conditions. During manufacturing, the processor lays the prepreg into a mold, where the resin is polymerized (usually at high temperature) into a near-final shape and the waste is cut away.

Azdel will dispense with much of the special handling by supplying fully polymerized composites that have been stamped or compression-molded into thin sheets cut to the customer's specifications, thus minimizing waste. And since the resin is already polymerized, the processor doesn't need special storage facilities or high-temperature equipment; the composite need only be heated to just below its melting point to mold the sheet to its final shape or to bond it to other materials, such as carpeting and decorative films.

The primary marketing goal for the composites is to replace much of the steel used in the automobile industry. Accordingly, Azdel is setting out to develop new automotive composites that will feature a smooth, steel-like finish that can stand up to the high oven temperatures needed for auto enamels; the company is also focusing on building materials (such as floors and gratings), pallets, and metal shipping containers. "Composite drums, for example, take 40 pounds off the weight of the container," says Brown.

Located near PPG's fiberglass facility, the Azdel plant is expected to produce 75 million pounds of composite this year. But for now the company will concentrate on thermoplastic composites traditionally sold under the Azdel brand name; these are based on polypropylene and polyethylene terephthalate combined with inexpensive glass fiber. New, more advanced thermoplastic systems—perhaps combined with specialty fibers, such as high-strength glass–carbon blends—will be developed at Azdel's technology center in Troy, Mich.

Despite the founders' solid technical credentials, Azdel's challenge to auto body steel is not assured of success, says analyst James Wilbur at Smith, Barney (New York). A widespread switch to composites could be defused, for example, by low petroleum prices, which in effect reduce the pressure on automakers to use plastics and other lightweight materials. Azdel also faces such big-league plastics competitors as Du Pont, Borg-Warner, and Mobay. "It's a very competitive market," says Wilbur, "with a lot of suppliers and new materials to choose from. It isn't easy for automakers to decide on the best way to go." □ —*H. Garrett DeYoung*

Michael Brown, manager of GE's technopolymers group, holds a prototype appliance base made from Azdel thermoplastic composites.

DATACOPY:

LINKING PCs TO FACSIMILE MACHINES

Facsimile machines, which transmit text and graphic images over telephone lines in a matter of minutes, have been around for some 10 years. But lately these systems have been gaining increased acceptance in the workplace because they are now affordable for most businesses (the average machine costs $3000). The installed base of 600,000 machines in the United States is expected to swell to 1.4 million by 1990, according to IDC (Framingham, Mass.).

Datacopy, of Mountain View, Cal., hopes to hitch part of its growth to this market with the MicroFax ($1195), a hardware and software package that allows IBM-compatible personal computers to communicate with the most common facsimile machines. And fax machines could be bypassed altogether if both sender and receiver had computers equipped with MicroFax.

"MicroFax technology should soon become the preferred way to transport letters, charts, and graphs because it runs with existing equipment and offers a lot of flexibility," says Rolando Esteverena, Datacopy's president. Documents may be sent either from the computer screen or from stored files. All operations take place off line, freeing the computer for other functions. Information may also be modified on the screen or stored for later transmission at the lowest phone rates; at present, only high-end fax systems, typically costing \$5000–\$6000, have memory and storage capabilities. In addition, MicroFax may be used with an optional scanner, costing upwards of \$1560, for transferring information directly from paper to computers. Many customers are expected to use scanners to save the time and cost involved in inputting documents by keyboard (the same advantage offered by facsimile machines).

Founded in 1973, Datacopy was among the first to introduce low-cost, high-resolution image scanners. Esteverena sees MicroFax as a natural extension of the firm's scanner products, which are expected to bring revenues of \$8 million in 1986, up from \$5.2 million the previous year. MicroFax should be well suited to companies that want to integrate their facsimile machines with computer networks, says Shelly Bakst, an analyst at IDC.

While MicroFax has few competitors at the moment, a flurry of other hybrid systems is expected within the coming year, says Bakst, since nearly all the traditional fax vendors—particularly the large Japanese manufacturers, such as NEC, Canon, and Sanyo—are exploring similar efforts. And Pitney-Bowes, one of the few American firms producing fax systems, has already released a computer-based package similar to MicroFax. But at this point, she says, there is room for more than one product, and Datacopy should be able to take advantage of its reputation as an innovator in the image scanning field.

A possible snag along the way is that using MicroFax with a scanner, as many customers may wish to do, could lead to storage problems, according to Nancy Erskine, an analyst at The Gartner Group (Stamford, Conn.). "It now takes an inordinate amount of memory to hold information from a scanned document," she says. Thus the shelf price of Datacopy's system doesn't always reflect the actual cost, since additional memory may be required to handle an office workload. Esteverena counters that it's possible to store an average of 300 pages on one 20-megabyte hard disk. This capacity, he says, is adequate for most corporate users, since urgent messages—the main traffic for fax—are not usually kept on permanent file. Meanwhile, he anticipates brisk sales of MicroFax over the next year, contending that "there are more than 8 million PCs in the U.S. waiting to be linked to fax."

—*Patricia Hittner*

Datacopy's president, Rolando Esteverena, with the Model 730 Scanner. In conjunction with MicroFax, the scanner can be used to input documents into IBM-compatible personal computers for transmission to facsimile machines.

DIGITAL COMMUNICATIONS ASSOCIATES:
GETTING IN ON THE T-1 BOOM

Digital Communications Associates (DCA), a 15-year-old company based in Alpharetta, Ga., has recently been laying the groundwork for increasing its penetration of several data communications markets. DCA currently designs, manufactures, and installs a broad range of data communications equipment, such as modems, protocol converters, and network management software. It was the first company to introduce the statistical multiplexer, a device that merges many slow-moving signals from different computer modems into one faster and more efficient data stream. It is also well known for the Irma board, which aids micro-to-mainframe communications by letting an IBM PC emulate an IBM 3270 mainframe terminal. By facilitating data transfer between different types of computers, these products have helped DCA's revenues climb from \$10 million to \$140 million between 1981 and 1986.

Over the past year, DCA has made a series of acquisitions and marketing agreements designed to extend its reach. It purchased Forte Communications (San Jose, Cal.), which makes graphics boards for personal computers and a micro-to-mainframe product that competed with Irma, and Microstuf (Roswell, Ga.), which publishes Crosstalk. The latter is a highly popular microcomputer communications program that has become an industry standard for using modems to access remote databases outside a company. (Microstuf was renamed Crosstalk Communications after its acquisition.) DCA also purchased from Telebit (Cupertino, Cal.) the right to market a personal computer modem that transmits data at up to 18,000 bits per second over ordinary telephone lines (most such modems pass data at 1200 bits per second).

But the company's most important move in 1986, analysts say, was the acquisition of Cohesive Network (Los Gatos, Cal.), which makes multipoint T-1 multiplexers. These devices are used by companies to channel and transmit voice and data communications at the T-1 rate (1.544 megabits per second) into and out of dedicated lines leased from telephone companies. DCA has long offered its own T-1 products, but these were limited to point-to-point communications (connecting two machines). Cohesive's technology allows

DCA president Bertil Nordin with rack-mounted modem cards for micro-to-mainframe communications.

for the creation of T-1 networks that interconnect many large computers.

DCA paid a high price for Cohesive—the $33 million purchase came at a time when Cohesive had $3 million in revenues and almost $7 million in losses—but it may be worth it. With a growth rate of 25% annually, the overall market for T-1 equipment is the fastest-growing area in data communications, according to Dataquest (Cupertino, Cal.); the installed base in 1986 was worth $292 million and should increase to $727 million by 1990. Thus DCA "had to get in now with somebody like Cohesive or be locked out of the multipoint T-1 market," says Mark Dunkel, research analyst at Robinson-Humphrey, an Atlanta-based brokerage. DCA is now grouped with Timeplex and Network Equipment Technologies on this cutting edge of data communications. DCA's president, Bertil D. Nordin, has a favorable track record in acquisitions. For example, the company paid more than $40 million in 1983 for Technical Analysis Corp (TAC), maker of the Irma board, when that firm had sales of less than $10 million. "There was concern at the time that DCA was paying way too much for TAC," says Alan Jenks, publisher of *Southeastern Business Letter* (Atlanta). But Nordin was proven right when Irma board sales took off with the boom in micro-to-mainframe communications, adds Jenks, and he could well be right again with multipoint T-1 devices. □

—Dana Blankenhorn

The second of three Australian communications satellites is now in service. Aussat 2 was launched from the space shuttle into geosynchronous orbit, 22,300 miles above Earth. After completing three weeks of testing in space by Hughes Aircraft Company, the Hughes satellite was turned over to Australia for operation. Aussat spacecraft are designed to unify the Australian continent and off-shore islands. Each uses three-reflector antenna systems, which produce seven transmit beams for regional and national coverage. The satellites carry direct television broadcasts, telephone service, digital data transmission, and provide centralized air traffic control.

Dangerous hot spots that could flare up after a forest fire can be located by rangers. Inspections are made by aiming a hand-held Hughes Probeye® infrared viewer while flying over the area in a helicopter. The Probeye viewer sees heat the way a camera sees light, converting it instantly into an image seen through the eyepiece. Additionally, mining officials report success using Probeye viewers to prevent fires, to search for lost or injured miners in smoke-filled passages, and to inspect structures, electrical systems, and mechanical equipment. The infrared viewer also detects concealed fires and potential spontaneous combustion sources, such as hot spots in coal beds and refuse dumps.

An automatic infrared test and diagnostics system inspects printed circuit boards more quickly and at less cost than conventional methods. The THERMOSCAN system uses a non-contact approach to test a variety of printed circuit boards and hybrid circuits. It can be used on production lines, repair depots, or intermediate repair facilities as a complement to automatic test equipment or as a screening and testing device for repairable boards. The system thermographically tests several good boards or hybrids and stores a standard temperature profile in computer memory. The unit under test is compared by the computer to the stored thermal profile, and differences are displayed on a screen. Suspect boards can be tested at a rate of up to 30 per hour. The Hughes THERMOSCAN system detects most component failures on printed circuit boards and hybrid circuits in a single test.

Cable TV subscribers in Northern California will get improved service with a new microwave system that distributes 40 channels from one centrally located site, near Davis, to hub sites in four non-contiguous communities. The new Amplitude Modulated Link (AML) system, developed and built by Hughes, makes it feasible to cluster Woodland, Winters, Dixon, and West Sacramento, each ranging in size from 900 to 13,000 homes, into one system serving nearly 30,000 homes. The array handles video, FM radio, and signal control data without the expense of cable trunks and other equipment and building facilities. Sonic Communications, the second-largest independent operator of multiple cable TV systems in California, expects that the system will bring both capital cost savings and operating economies.

Hughes' Santa Barbara Research Center is seeking experienced engineers and scientists to further develop advanced IR systems. We need design engineers, nuclear effects engineers, instrumentation engineers, electro/optical packaging engineers, IR system analysts, and project leaders. To learn how you can become involved in the development of new IR systems, contact the Santa Barbara Research Center, Professional Employment, Dept. S2, 75 Coromar Drive, Goleta, CA 93117. Equal opportunity employer. U.S. citizenship required for most positions.

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PARALLEL COMPUTERS DIVERGE

The trend toward multiple-processor machines has spawned almost as many different architectures as vendors

BY DWIGHT B. DAVIS

A cursory look at the computer business these days might seem to indicate a rapid transition from single-processor to parallel-processor machines—those with tens, hundreds, or even thousands of processors bundled together in a single box. During the past couple of years, at least 25 vendors have unveiled what they call parallel computers, while predicting the eventual demise of traditional serial machines. The latter, they say, are too expensive and are pushing the limits of their power.

Despite the hoopla, however, most parallel processing still takes place in research labs, not in commercial application environments. And of the multiple-processor machines sold today, only a small percentage perform "true" parallel processing, in which the nodes—independent processing units—join together to speed the execution of a single program. A lack of software for achieving parallelism is a major factor limiting commercial use.

Still, most industry observers agree that parallel processing has a bright future. The rationale is simple enough. To achieve increased power, single-processor computers must constantly incorporate faster and more expensive circuitry. At the extreme end of the processing scale, where supercomputers ply their trade, single processors run into insurmountable physical barriers. Circuit switching speeds start to reach their ultimate limits, and components must be positioned closer and closer together to reduce the distance electric signals must travel. At some point, however, this compactness exceeds the ability of the circuits to dissipate the generated heat.

Parallel computers, on the other hand, achieve their speed by dividing up the problem and processing its parts simultaneously on multiple computing nodes. The individual nodes can range from extremely rudimentary processors to industry-standard microprocessors to supercomputer-level CPUs, they can be combined in a wide range of numbers, and they can be linked with a variety of communications schemes. These options have already resulted in a spectrum of multinode computers aimed at market sectors as diverse as on-line transaction processing and fluid-flow simulation studies.

How vendors define parallel processing and how they implement it also varies considerably. Likewise, the applications that suppliers target often have little in common. As a result, debates about which parallel architecture is "best" often have little relevance to computer users. "Only one in 100 customers is concerned with architectural distinctions," notes Peter Appleton-Jones, president of vendor Elxsi (San Jose, Cal.). "Most just want performance."

Nonetheless, a computer's architecture inevitably defines its range of applications. The most fundamental design decision—one long debated within the parallel-processing community—involves the number of processors to build into a system. At one extreme are vendors like Cray Research (Minneapolis), which argue that a small number of very powerful processors linked together represents the best overall design. Such a "coarse-grain" approach, they say, eliminates the difficulties involved with breaking problems into many parts; the power of the individual processors, meanwhile, ensures that portions of the code that must run serially will execute rapidly. Such serial code can be the downfall of a parallel machine if it is unable to process the code quickly, notes Gene M. Amdahl, chairman of Trilogy, Elxsi's parent company. "What limits your high performance," he says, "are the things you do poorly, not what you can do well."

At the other end of the spectrum are companies like Thinking Machines (Cambridge, Mass.), which promote the concept of massively parallel processors. These "fine-grain" machines combine thousands of relatively weak nodes that, in concert, can form extremely powerful computers. Because the individual processors are in-

DANA SIGALL

Alliant's Richard McAndrew claims that the company's FX series of computers are the only products now able to create parallel code automatically.

expensive, proponents claim, massively parallel machines that match or exceed the speed of coarse-grain parallel processors can cost considerably less. And despite widespread skepticism, proponents believe that fine-grain computers will prove to be applicable to most types of computer problems, not just to a restricted subset.

Most commercial parallel machines fall somewhere between these two extremes. They offer tens or hundreds of processors, often based on general-purpose microprocessor chips such as the Intel 80286, the Motorola 68020, or the National Semiconductor 32032. But what really distinguishes these "mid-grain" machines is how the processors are connected. Although a variety of connection schemes exist, two fundamental types have emerged. The first design is a bus-based architecture, in which the various processing nodes, as well as the memory and input/output (I/O) facilities, reside on a common communications bus—or set of buses. Most computers of this type incorporate a "global" memory approach in which all the processors share a central memory that they access via the communications bus.

The second major design category is the hypercube, or n-cube, in which each processing node is directly connected to n of its neighbors. The number of connections per node results in a multidimensional cube with 2^n nodes—a hypercube with five interconnections per node consists of 32 nodes, one with seven interconnections contains 128 processors, and so on. Typically, the cube-based systems have "distributed" memory schemes that place local memory at each computing node.

Within both the bus-based and the cube-based camps are widely divergent machines that vary in the power and number of processors they incorporate, in the amount of memory supported, in the speed of the internodal connections, in the level of I/O they offer, and in the software tools they provide. But both approaches are characterized by certain fundamental capabilities and limitations.

BUS-BASED MACHINES. Vendors offering bus-based multinode architectures include Alliant (Littleton, Mass.), Elxsi, Sequent Computer Systems (Beaverton, Ore.), Encore Computer (Marlborough, Mass.), Flexible Computer (Dallas), Cray Research, Convex Computer (Richardson, Tex.), Masscomp (Westford, Mass.), and Concurrent Computer (Tinton Falls, N.J.). A major advantage these vendors realize from the bus architecture is its familiarity; traditional serial computers also use buses to connect their various components. In effect, all the multinode systems do is place more than one CPU on the bus.

But in reality, such a step is far more complicated than it seems. With additional processing nodes, the system bus can rapidly become congested with instructions and data passing between the processors and the common memory. I/O ports, meanwhile, can bog down under the increased load. As Nicholas Matelan, Flexible's president, notes, "Anyone who builds a machine with more than one processor has to be in the communications business more than the computer business."

An obvious first step of the bus-based designers is to build an extremely fast system bus. For example, Encore's Multimax incorporates a 100-megabyte-per-second "Nanobus," and Elxsi's System 6400 "Gigabus" operates at 320 megabytes per second. Even higher speeds are possible thanks to the advent of optical fiber links. A fast bus alone, however, just gives the potential to support multiple computing nodes. System software is required to allocate jobs to each node, memory accesses must be supervised to avoid contention for the same data, and all of the results must

be appropriately collated and routed.

At some point, parallel machines that rely on a common bus to access a global memory—even those using optical fiber—inevitably face communications overload. This class of machines, therefore, rarely supports more than 10–20 processors and is limited in the long run by the power of each node. This can still result in exceedingly powerful machines, as demonstrated by the four-processor Cray X-MP48, which attains peak speeds of 1000 million floating-point operations per second (MFLOPS) or more. (Peak MFLOPS ratings indicate the speed with which a vector-processing computer—one that can simultaneously process ordered sets of numbers such as matrices—can run a program that is 100% vectorizable, a rare bird indeed. The other common measurement, millions of instructions per second, or MIPS, indicates how fast a computer can serially process integer data.) But most observers agree that the cube-based architectures offer the potential for greater long-term expansion.

One solution to the bus-imposed limitation is to reduce the bus traffic as much as possible. Flexible achieves this by building its Flex/32 with a design commonly referred to as a multicomputer. Under this approach, each processing node contains its own local memory and I/O capability, and runs its own copy of the operating system. As a result, "a multicomputer allows the instructions, which are probably 80% of the typical traffic, to be locally contained at each processor," Matelan explains. The Flex/32 also supports a global memory, but "only when you need shared information does it go over the common bus to the shared memory."

Multinode machines seek to take advantage of the parallelism inherent in many applications.

This architecture has the advantage of increased expandability—while the largest Flex/32 sold to date consists of 40 nodes, Flexible claims a theoretical limit of 20,840 processors—and of being able to mix different types of processors in the same system. Flexible already offers two processor modules, one based on the National Semiconductor 32032 microprocessor, the other incorporating Motorola 68020 chips. By contrast, all other multinode systems combine identical processing units. Still, without user programming, the Flex/32 is unable to perform single-problem parallel processing, especially when using nodes based on different processors. Like the other bus-based machines, therefore, it usually serves in a multiprocessing-type environment, in which several similar problems, rather than a disaggregated single problem, are simultaneously processed (see "Degrees of parallelism").

CUBE-BASED MACHINES. Computers based on the hypercube architecture are rarely promoted for use as multiprocessors. Their distributed memory architectures don't readily lend themselves to such applications, which usually require a large shared memory. These are parallel machines, first and foremost, and their manufacturers include Intel Scientific Computers (Beaverton, Ore.), Thinking Machines, Floating Point Systems (Beaverton, Ore.), NCube (Beaverton, Ore.), and Ametek Computer (Arcadia, Cal.). These vendors believe that whatever their computers may lack in compatibility with traditional serial machines, they make up for in computing power and potential.

Intel, the first company to market a cube-based computer, offers a relatively modest 64-processor configuration as the largest in its iPSC-VX line. Still, this top-of-the-line model promises a peak performance of 424 MFLOPS, well within the supercomputer class. Floating Point's T-Series, on the other hand, offers the broadest range of cube configurations, starting with the eight-node T/10 and growing to the massive 16,384-node T/

DEGREES OF PARALLELISM

While most vendors agree on the inherent advantages of parallel processing, they often disagree on what rightly falls into that category.

The ability of computers to perform multiple tasks simultaneously is nothing new. At the individual instruction level, a single processor can contain hardware "pipelines," which work in assembly-line fashion on arithmetic operations. Each stage of the pipeline is designed to perform a specific step of a task and then pass the results along the pipeline for the next step. For example, individual "multiplies" might each require four instruction cycles to reach completion. A four-stage pipeline could accept a stream of multiply operands, one after the other, and move them from stage to stage with each machine cycle. After four complete cycles, the results of the first multiply would exit the pipeline, the results of the second multiply would follow on the fifth cycle, and so on. If done totally sequentially, the second four-step multiply would finish on the eighth cycle, not the fifth. Since its introduction in the 1960s, pipelining has become a common technique in many of today's high-end machines.

At a slightly higher level of parallelism, designers can incorporate multiple functional units within a single CPU. Most jobs include a mix of adds, multiplies, divides, memory fetches, and so on, and individual components dedicated to performing each of these tasks can often be made to run simultaneously.

Some designers take this basic concept a few steps farther and build their systems with several processors that are dedicated to performing more complex, higher-level tasks. For example, Culler Scientific Systems (Santa Barbara, Cal.) combines one machine for addressing memory and moving data and another machine for numerical computations on each of its user processors. Both machines, in turn, are built with multiplier and other arithmetic components to achieve instruction-level parallelism as well. "By some definitions, we don't do parallel processing," admits Larry Evans, vice-president of manufacturing, "but we do provide 'functional' parallelism. We split problems into functional blocks for simultaneous execution."

Another popular technique, sometimes achieved through pipelining, is vector processing, in which the same instruction is repeated on a number of items in a list. Multidimensional vectors, or matrices, can also be processed simultaneously in some machines. Vector processing has proven especially useful in scientific and engineering applications such as physical simulations, in which the mathematical models are often inherently "parallel." The limitation to this technique, however, is that some of the software code is inherently scalar—non-vectorizable—and subject to "Amdahl's Law," which essentially states that the speed of any process is limited by the slowest of its operations.

To overcome such barriers, designers began to experiment with systems that combined more than one full-blown processor. They reasoned that individual software programs often contain branches and segments that are totally indepen-

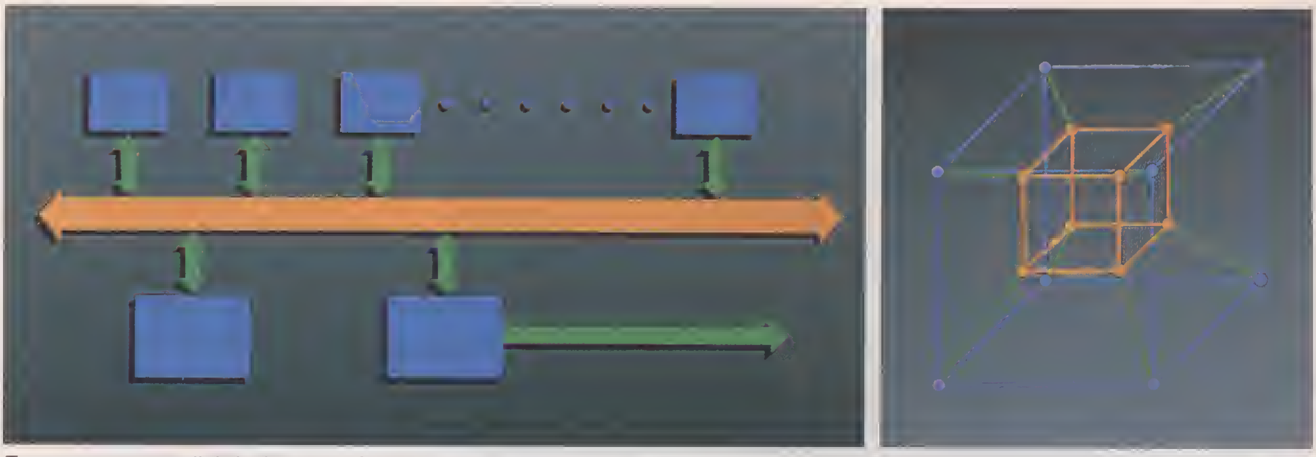


IMAGE BUILDERS

Two common parallel designs are the bus-based (left), which uses a single communications bus to link a variable number of processors to memory and I/O modules, and the hypercube, which connects processors (each with its own local memory) to a set number of neighboring nodes. For example, a hypercube with four links per node (illustrated) has a total of 2^4, or 16, nodes.

40000, with a theoretical peak speed of 262 billion floating-point operations per second (GFLOPS).

The distributed-memory architecture of the cube machines is viewed cautiously by some observers, who question the number of applications that can take advantage of it. Some applications—those consisting of similar processes that can be broken up and performed virtually independently—are inherently suitable. In image processing, for example, an image can be divided into hundreds or thousands of parts, which can then be distributed to a cube's nodes for simultaneous processing.

But although "the hypercube topology is probably going to be very effective for certain applications," says Jeffry Canin, an analyst with Hambrecht & Quist (San Francisco), "it is suited to a narrower set of applications than that of the bus-based machines." Such claims don't convince Omri Serlin, president of research firm ITOM International (Los Gatos, Cal.) and editor of *Supermicro*, a newsletter that covers the parallel-processing market. "Although the bus-based multiprocessing approach is the winner today," he says, "the parallel approach that seems to have the most potential over time is the hypercube." Serlin notes that the hypercube systems have far greater expansion capability than the bus-based systems, and also that the cubes are being embraced by a variety of vendors.

SOME OTHER APPROACHES. While bus-based and cube-based machines are the most common multinode designs, they don't represent the whole of parallel processing. For example, a "binary tree" structure developed at Co-

dent of one another and that can be distributed to different processors for execution in parallel. But simply combining two or more processors in a single box does not necessarily result in single-program parallel processing. Some of the first commercial systems so configured were the fault-tolerant machines built by companies such as Tandem Computer and Stratus Computer for transaction-processing applications. In these machines, the multiple processors served two important purposes: they provided backup capability to take over if one processor failed, and they handled separate job streams submitted by different users. The first capability is known as fault tolerance, the second as multiprocessing. As it turns out, multiprocessing is the manner in which most multinode systems are functioning today.

In parallel processing, a single program is divided among multiple nodes to improve its "runtime." But in multiprocessing, the nodes run totally different applications or independent job streams of the same general application in order to improve the overall "throughput," or the number of tasks processed per hour. An example of the latter might be an insurance company's 10-node multiprocessor containing a common claims database in a common memory that 10 agents can access simultaneously. The agents would work in parallel within the same database application, but would perform totally independent tasks that required little or no interaction between the processing nodes.

Theoretically, many multinode computers can function as multiprocessors, as parallel processors, or as mixtures of the two. In practice, though, multiprocessing is the rule, and parallel processing the exception. For example, only about 20% of the multinode Balance computers sold by Sequent Computer Systems (Beaverton, Ore.) are used in parallel processing applications, according to Michael Simon, VP of marketing. And Frank Marshall, VP of development at Convex Computer (Richardson, Tex.), says surveys have shown that 95% of the Cray X-MP48 supercomputers—which he calls "the world's most successful parallel processor"—are, in fact, performing as multiprocessors. A Cray spokesman says that this figure is probably high, but agrees that the vast majority of the multinode supercomputers are not currently involved in single-job parallel-processing tasks.

The vendors make no apologies for the fact that many of their machines serve primarily as multiprocessors. "Most business automation functions are one big application that is multiuser and multithreaded," says Simon. This is the computing world in which the multiuser, multitasking Unix operating system has become a standard, and most multinode vendors offer Unix-based operating systems on their machines. This gives them the big advantage of being able to run existing applications without the users having to rewrite any software code. The computers' system software takes the multiple job streams and assigns them to available processors, where each runs independently on its assigned CPU.

"The multiprocessing approach to parallel processing is where the commercial and industrial money is going today," says Marshall at Convex, which recently added a four-processor machine to its C-1 minisupercomputer family. "There's more business going on there than in this area of trying to split one particular algorithm across multiple machines. That's an area of experimental science."

lumbia University is being brought to market by Fifth Generation Computer (New York). This design links each processor to two lower processors, which in turn are each linked to two lower processors, etc. Goodyear Aerospace (Akron, Ohio), meanwhile, sells a machine containing 16,384 processors, each with 64K bits of local memory, in a two-dimensional 128 × 128 grid.

Another approach, relying on a switching network to connect large numbers of processors, is commercially implemented in the Butterfly computer from BBN Advanced Computers (Cambridge, Mass.). Processors that must communicate do so via the switch, which establishes temporary logical connections between nodes as needed and is able to expand with the number of processors, up to a maximum of 256 nodes. Although memory is distributed within each Butterfly processor, the system can logically combine the memory to function as if it were a global shared memory. Each processor is thus able to run all its program instructions out of the local memory, cutting communications overhead, but can share data when necessary, according to Gary E. Schmidt, VP of marketing.

Truly general-purpose parallel computers need software tools to divide programs automatically.

Even in the more common parallel architectures, there are differences in how software is logically organized to run on the hardware. One example is Thinking Machines' Connection Machine, a hypercube-type design that comes in 16,000- or 64,000-processor versions and that breaks up problems in an unusual way. Rather than distributing portions of a program to each node, the computer loads different data elements in each of its rudimentary processors and then executes the same instruction on all the elements simultaneously. In certain applications, processing rates of as high as 7000 MIPS can be reached.

This distributed-data approach is often referred to as single-instruction multiple-data (SIMD) processing; it has existed for years, but rarely at such a massive level as the Connection Machine achieves. Competitors argue that SIMD processing is much more limited in application than the more common parallel approach—multiple-instruction multiple-data (MIMD) processing. Yet Daniel Hillis, founding scientist at Thinking Machines, insists that his is "a

Representative parallel/multiprocessing computers

Company/product	Price	No. of processors	Processor type	Memory	Architecture
Alliant FX series	$100,000–$1 million	1–8	custom	shared	bus
Ametek Computer System 14	$75,000–$890,000	16, 32, 64, 128, 256	80286 & 80287	local	hypercube
BBN Butterfly	$7000–$9000 node	2–256	68020 with custom coprocessor	shared & local	switched network
Concurrent Computer 3280	$250,000–$1 million	1–6	custom	shared	bus
Convex C1 XP	Starts at $475,000	1–4	custom	shared	bus
Cray X-MP	$8.5–16 million	1–4	custom	shared	bus
Culler PSC	$98,500	1–2	custom	shared & local	multiple buses
Elxsi 6400	$369,000–$3 million	1–12	custom	shared & local cache	bus
Encore Multimax **	Starts at $100,000	2–20	32032	shared & local	bus
Fifth Generation Computer	$26,000–many millions	4–8192	68020	local	binary tree
Flexible Flex/32	Avg. price $200,000	Up to 20,480	32032 & 68020	shared & local	bus
Floating Point T-Series	Starts at $500,000	8–16,384	Transputer	local	hypercube
Goodyear Aerospace MPP	$3–3.5 million	16,384	custom	local & shared	mesh
Intel IPSC-VX	$250,000–$850,000	16, 32, 64	80286 & 80287; 3220 & 3210	local & shared	hypercube
Loral LDF 100 DataFlo	$67,000–$1.9 million	5–256	32016	local & shared	dataflow bus
Masscomp 5700	$88,400–$350,000	1–4	68020 & 68881	shared	multiple buses
NCube	$10,000–$1.5 million	4–1024	custom	shared & local	hypercube
Sequent Balance 2100	$139,000–$500,000	2–30	32032	shared	bus
Thinking Machines Connection Machine	$1 million or $3 million	16,384 or 65,536	custom	local	hypercube

* 64-bit, double precision ** Encore is slated to have announced an upgraded computer product by the time this issue appears.

NOTE: for a list of company addresses and phone numbers, see **RESOURCES**, p.65.

general-purpose machine," noting that it has already proven itself in applications as diverse as searching text databases, assisting in chip design, and performing seismic processing, image analysis, and fluid-flow simulations. "After you get into such a wide variety of things," he says, "you start to get pretty confident that it will be applicable to most problems."

HOW GENERAL IS GENERAL-PURPOSE? Like Hillis, almost every vendor of a multinode computer claims to have a general-purpose machine. Only a few—such as Teradata (Inglewood, Cal.), which markets a parallel database management machine—admit to having a system that is best suited to a specific niche. "General-purpose," it turns out, is a term even more vague and misused than "parallel processing." Most ven-

Peak performance	Target markets
94 MFLOPS * 35.6 MIPS	Scientific/engineering
12–15 MFLOPS *	Scientific/engineering
256 MIPS	Scientific/engineering; AI
34 MIPS	Scientific/engineering; transaction processing
25.5 MIPS	Scientific/engineering
1 GFLOPS *	High-end scientific/ engineering
5 MFLOPS *	Simulation & modeling; graphics
7–84 MIPS (mod 1), 13–156 MIPS (mod 2)	Aerospace/defense simulation; real time
15 MIPS	Technical R&D; software development; commercial
14 BIPS	Signal processing & symbolic processing
3.5 MIPS/processor	Real-time scientific/ engineering aerospace
16 MFLOPS * & 7.5 MIPS/processor	High-end scientific/ engineering; AI
470 MFLOPS	Aerospace/defense
424 MFLOPS *	High-end scientific/ engineering
5–256 MIPS	Scientific/engineering
2.5–10 MIPS 13–52 MFLOPS	Real-time data acquisition; scientific/engineering
500 MFLOPS, 2000 MIPS	Scientific/engineering; database; AI
2.8–21 MIPS	Scientific/engineering; commercial; database
More than 1000 MIPS	High-end scientific/ engineering; text searches

RICH IWASAKI

Sequent's Michael Simon (right) and director of product marketing Richard Gimbel claim that their computers can greatly speed up existing application software without requiring special programming.


RAYMOND GENDREAN

Convex's Frank Marshall (right) and Jim Balthazar, manager of product marketing, say true parallel processing is highly experimental and still not of much use in today's marketplace.

WILLIAM COUPON

Thinking Machines' Daniel Hillis notes that government and university labs are more likely than industry to take the initial risk of acquiring novel computers.

dors are referring to potential, not practice, since the number of applications running in true parallel mode is still limited.

To be truly general-purpose, the computers need system software tools that automatically subdivide programs. Some industry participants predict widespread availability of such tools within two or three years, although others say at least five years is more likely.

Alliant's Fortran compiler is generally acknowledged to be the first commercial product able to automatically take existing code and exploit some of its inherent parallelism. Many programs contain "loops" of code that are repeated, each time with different data inputs. Often, loops exist within loops in a "nested" fashion. The Alliant Fortran compiler finds program loops and first determines if they can be vectorized; if so, they run in vector mode on an individual processor. In addition, the compiler spots loops that can't be vectorized, because each successive iteration of the loop depends on data generated by the previous iteration. "We can automatically run many of those iterations simultaneously on parallel processors," says VP of development Richard McAndrew. "The hardware and software manage both the assignment of the iterations and the synchronization of the data dependencies between those iterations."

This type of parallelism, which McAndrew calls microtasking, is very useful in the scientific and engineering applications—such as electronic circuit simulation, molecular modeling, and finite element analysis—that Alliant addresses. But a higher level of parallelism, "macrotasking," is needed to fully exploit other types of applications. For example, a flight simulator might have independent modules that control different parts of the simulation. One segment of the program might control pitch and yaw, another the positioning of the ailerons. "Each of these independent parts of the problem could be assigned to its own processor," says McAndrew, "but today there are no automated methods for doing that."

Although the race to achieve such automatic, macrotask parallelism is well under way within vendor and university laboratories, many think results are at least five years away. In the meantime, says Flexible's Matelan, "to get the big bang out of parallel processing, you've got to write some code."

Given this situation, many vendors are attempting to make their products as compatible as possible with the software that already exists in their target markets. Inevitably, most of that software now runs on IBM and Digital Equipment computers, and the multinode computer suppliers are trying to take advantage of the fact that neither of the two major vendors yet offers a parallel machine. IBM has for some time pursued research in this area, but "I don't see any evidence that either IBM or DEC is anywhere near releasing a true parallel-processing architecture," says Serlin of ITOM International. "Neither will get seriously involved in this field until they see solid evidence of commercial success."

The absence of the giants gives the parallel vendors an opportunity to attack IBM's and DEC's traditional markets by claiming to offer faster hardware on which to run customer's existing software. For example, Elxsi sells a family of products called the EMS Environment that makes its System 6400 closely compatible with DEC's VAX computer line. "A fully configured System 6400 offers up to 24 times more memory than DEC's top-of-the-line VAX 8800 and more than six times the processing power," claims Elxsi president Appleton-Jones.

Of course, the markets targeted by the parallel-processing suppliers span a wide range, as does the degree of each product's compatibility with existing software. If the parallel products have anything in common, it may be the belief among their builders that the machines will eventually prove more suitable than serial processors for most computing applications. "There are some algorithms in business and nature that are very serial in form," explains Serlin. "But by and large, if you look at the universe around you, it's mostly parallel."

The expandability of parallel computers is also considered a selling point. With serial processors, users who run out of computing power must typically buy a bigger computer. With parallel machines, the users have the option, within limits, of simply adding new nodes to the box. They are thus able to grow in smaller increments than might be required with a serial product line.

But even these properties don't necessarily exhaust parallel processing's advantages, say its advocates. "What's exciting and interesting about this whole area is that parallelism is a new technology," says Alliant's McAndrew. "What we understand today is really the tip of the iceberg." □

Dwight B. Davis is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES,** *p. 65.*

New Commercial Aircraft Promise Efficiency

Miserly engines and lightweight bodies could help keep airlines aloft

By T. A. Heppenheimer

Today's airlines must economize in order to stay alive. Realizing this, manufacturers have started to design a new generation of commercial aircraft that will cut airlines' costs per trip by about a third. The new craft, which should enter service in the early 1990s, will incorporate new fuel-thrifty engines, drag-reducing improvements in aerodynamics, lightweight materials, and advanced avionics and control systems. Many of these developments are strongly synergistic. For instance, economical engines reduce the weight of fuel, and hence an aircraft's structural weight. The lighter airplane can then fly with smaller engines. Advanced materials reduce weight further, again driving down the fuel's weight and bringing another round of improvements in economy. It is this "virtuous cycle," unprecedented in aviation, that will create the third generation of modern airliners, according to their developers.

The first jet-age generation, exemplified by the Boeing 707 and 727 and the Douglas DC-8, dates back to the 1950s and early 1960s, when jet fuel cost 10¢ a gallon and airlines could emphasize speed alone. The second generation, starting in the late 1960s, introduced fanjet engines for improved economy and low noise, and ushered in the widebodies: Boeing's 747 and 767, Douglas's DC-10, Lockheed's L-1011, and the European A300 Airbus. Today, says Boeing senior director Mark Kirchner, "the goal is low cost." Two programs already under way, and a third waiting in the wings, represent the coming generation of aircraft with that dominant characteristic:

- **THE 7J7.** This 150-passenger aircraft, to be built by Boeing (Seattle) in an equity partnership with the Japanese firms Mitsubishi, Kawasaki, and Fuji Heavy Industries, is a potential replacement for the 727 series, of which more than 1200 planes are now in service. Boeing is still testing alternative approaches to such basics as the material for the aircraft's wings. The company expects to freeze the 7J7's design in mid-1987. If enough orders arrive, the plane will enter service in 1992.
- **THE MD-91 AND MD-94.** Douglas Aircraft (Long Beach, Cal.) envisions the MD-91 as a re-engined version of its MD-80 twin jet. The company plans to introduce the 110-passenger plane in 1991, and the 180-passenger MD-94, incorporating a full range of advanced materials and aerodynamics, three years later.

ILLUSTRATION BY DENNIS DAVIDSON

Rear-mounted propfans (jet engines with external propellers) will give new airliners impressive fuel economy.

• THE 747-500. The 7J7 and the two Douglas aircraft will serve the market for planes of medium size and range, but will not compete with long-range widebodies. The 747-500—now under study at Boeing, although not yet inaugurated as a formal program—could become the leading jumbo jet of the next generation. With a range of 7500 nautical miles, it would carry over 500 passengers in a double-deck configuration, using new and extremely economical engines and lightweight wings that induce less drag.

The current marketing success of Boeing's not-yet-released 747-400 indicates the bonanza awaiting manufacturers who can offer even modest improvements in performance and economy. The plane has a range of 8000 nautical miles—1000 more than current versions of the 747—which it achieves by carrying more fuel and using engines about 10% more fuel-efficient than those now in use. It has a two-person electronic cockpit, wings designed to reduce drag, and lightweight carbon brakes from BFGoodrich (Akron, Ohio). With all this, it still represents only an incremental improvement over present 747 models, and is far from being a next-generation airliner. Yet it has emerged as an outstanding commercial success almost two years before its first scheduled deliveries. Last March, Singapore Airlines set an aircraft-purchase record when it placed a $3.3 billion order for 14 of the 747-400s, with options on six more. That record stood for just four months. In August, British Airways ordered 16 of the new planes with options on 12 more, at a cost of $4.1 billion.

Fuel economy will be the hallmark of the new generation of aircraft. But given the low level of current oil prices, airlines are less willing than in previous years to pay capital premiums for fuel savings. In 1970, according to Boeing, airlines could afford a 4% higher price for a 10% improvement in fuel efficiency. By 1980 they could pay 16% more. But today, for that same 10% fuel saving, airlines can pay a premium of only 2.5%. So manufacturers working on third-generation aircraft must offer significant fuel savings or relatively low prices, or both.

The process of building new fuel-efficient planes starts with the engines. Designers aim to minimize a quantity known as the specific fuel consumption—the amount of fuel, in pounds, needed to produce one pound of thrust for one hour. The turbojets of a quarter century ago had a specific fuel consumption of about 1.0 pound. Present-day turbofans have cut this to about 0.5. But in ground tests in 1985, a new engine from General Electric (Cincinnati) designed for third-generation aircraft set a record of 0.24 pound. Engines in day-to-day airline service are unlikely to approach that figure, but they do seem capable of specific fuel consumptions of 0.35 to 0.4 pound.

To develop new aircraft engines, manufacturers have reached back into the past and resurrected the propeller.

To develop the new engines, manufacturers have reached back into the past and resurrected the propeller. But they have gone far beyond the technology used in yesteryear's turboprop planes. The new engine is called a propfan, and its objective is to improve what engineers call the bypass ratio. This is the ratio of air that a fan drives past the core of a jet engine to that actually flowing through the core. Experience with conventional fanjets shows that increasing the bypass ratio greatly improves the efficiency, and hence the fuel economy, of jet engines.

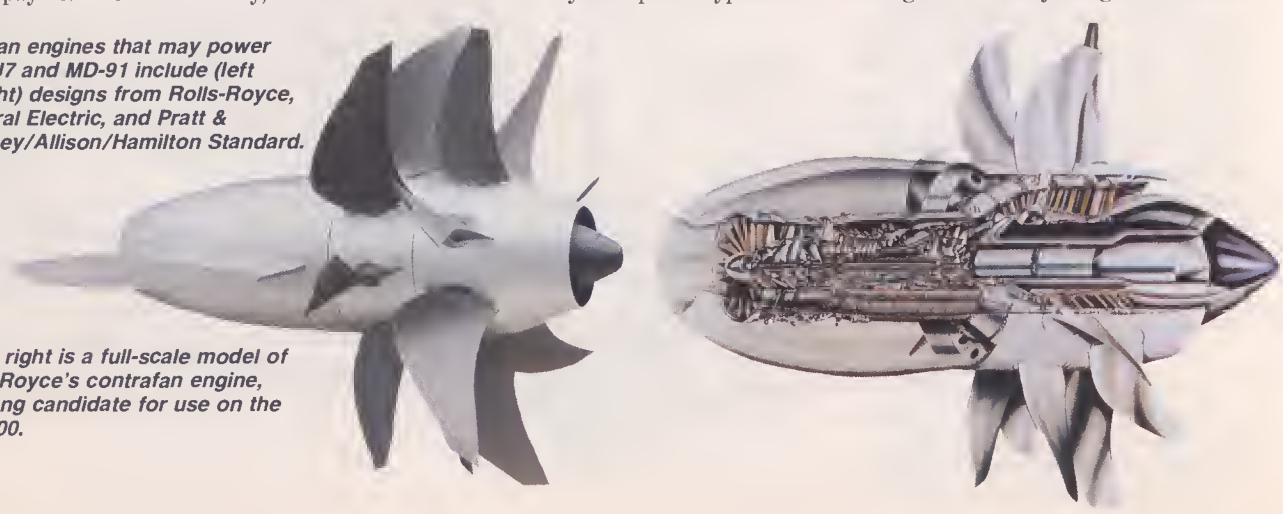
The obvious way to improve bypass ratios—using larger fans—encounters a major difficulty. Because they are much wider than the compressors in jet engines, fans must rotate more slowly. The standard turbofans in modern aircraft feature a "two-spool" design, in which concentric shafts drive the compressor and the fan at different rates. But as the fan becomes larger still, the mismatch in speed makes the arrangement aerodynamically unsound; hence the fan may require a gearbox if the turbine is to drive it properly.

Aero-engine designers have never liked gearboxes. They cause too many maintenance headaches. However, General Motors' Allison Division (Indianapolis), which has gained about 100 million hours of operating experience with gearboxes in military turboprops, hopes to quiet that concern by introducing gearboxes that run for 10 years without replacement. Allison is using computer-aided design to develop small, powerful gearboxes, as is Pratt & Whitney (East Hartford, Conn.). Hamilton Standard (Windsor Locks, Conn.) has added another wrinkle—an electronic system that can change the pitch of the fan blades.

The resulting engine, called a geared turbofan, or ducted fan, is a type of propfan that offers about a 15% improvement in fuel economy over today's turbofans. Rolls Royce has recently displayed a full-scale mockup of its proposed "contrafan," which uses counterrotating fans for additional efficiency. The second fan in effect straightens out the swirling flow from the first, and prevents its energy from dissipating. This type of fan, in fact, is a prime candidate for the new 747-500; it is compatible with a widebodied plane because it can be wing-mounted (a prerequisite for jumbo jets) without demanding major redesign of the wings.

This approach has its limits. Efforts to gain further economy by making the fan still larger fail because they also increase the weight and drag of the cowl—the housing around the jet engine that chan-

Propfan engines that may power the 7J7 and MD-91 include (left to right) designs from Rolls-Royce, General Electric, and Pratt & Whitney/Allison/Hamilton Standard.



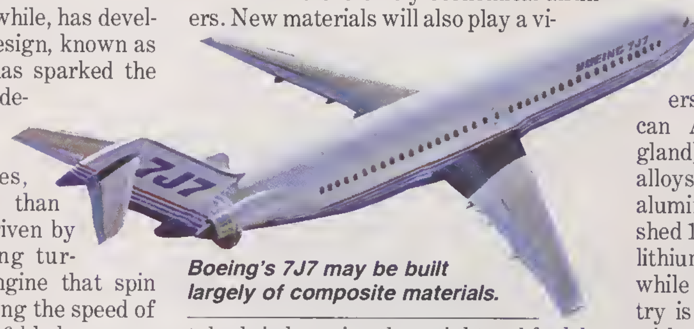
At far right is a full-scale model of Rolls-Royce's contrafan engine, a strong candidate for use on the 747-500.

nels the air blown by the fan before it combines with engine exhaust. The obvious way out is to get rid of the cowl. But without any covering, the tips of the fan blades would spin in the open air like a propeller, and in combination with the speed of the airliner, they would exceed the speed of sound; the resulting shock wave would carry off energy and create considerable noise. One partial solution, which will apply to the 7J7 and the new Douglas aircraft, is to design the propfan's blades in the shape of boomerangs. With their tips swept back like the wings of supersonic aircraft, the effect of the shock waves would be reduced.

General Electric, meanwhile, has developed a unique gearless design, known as the unducted fan, that has sparked the most interest among the designers of the 7J7 and MD-91. The trick involves relatively small blades, which can rotate faster than most blades. They are driven by auxiliary counterrotating turbines within the core engine that spin slower than usual, matching the speed of the blades. The engine's 16 blades generate 15,000 horsepower—three times the power of the military turboprop engines built by Allison—but it weighs just 6000 pounds. Last August, a Boeing 727 airliner fitted with one such fan began flight tests over California's Mojave Desert. The engine will undergo tests this year on a Douglas MD-80. Allison also has a demonstration geared propfan that will fly aboard an MD-80 in 1988.

Noise remains a problem for cowl-less fans. The level is acceptable during taxiing, takeoff, and landing, since the combined velocity of the blades and the airliner stays below the speed of sound; but at cruising speeds the combined velocity is supersonic. The resulting shock waves would disturb passengers and quite possibly weaken the aircraft's structure through fatigue. However, designers can largely overcome the difficulty by mounting the engines at the rear of the aircraft, in a pusher configuration, and treating the aircraft's rear fins and fuselage with sound-absorbing material such as aluminum-core honeycomb and fiberglass. Douglas Aircraft sees a market advantage here, because its MD-80 is the only airliner now in production that has twin rear-mounted engines. Derek MacWilkinson, a senior staff engineer at Douglas, explains that the company will create its MD-91 by substituting propfans for the MD-80's turbofan engines.

Fuel-sparing engines represent only one route to extremely economical airliners. New materials will also play a vital role in lowering the weight and fuel demands of aircraft. Composites, consisting of fiber embedded in epoxy, offer weight savings of 25 to 30% over standard aluminum. So far, manufacturers have used them for rudders, elevators, ailerons, spoilers and other parts of the flaps, landing-gear doors, engine cowlings, and wing-to-body fairings. Designers regard these parts as airliners' "feathers"—items that, because they are not critical structurally, can be easily replaced if the composites show problems in service.



Boeing's 7J7 may be built largely of composite materials.

The next step is to use composites for airliners' major structures, following the lead of business aircraft manufacturers such as Beech Aircraft (Wichita, Kans.), whose Starship features an all-composite design. Among other advantages, the increased stiffness of composites permits longer and slimmer wings, which produce less drag. Boeing is currently building an experimental wing made of composites for the 7J7, which it will test late this year. The major criterion is that the wing must be able to sustain the type of "limit load" that an airliner might experience just once in its lifetime—and do so after it has seen several years of service.

The extraordinary weight saving of composites does not entirely compensate for a major drawback: they lose much of their cost advantage when they contain numerous cutouts for such necessities as the doors and windows of fuselages—features that are harder to produce in composites than in metal. As a result, aluminum vendors have their own opportunity to participate in third-generation airliners. Alcoa (Pittsburgh) and British Alcan Aluminium (Gerrards Cross, England) have developed aluminum–lithium alloys that weigh 8% less than standard aluminum; that would permit a 747 to shed 11,000 pounds. The 2.8% by weight of lithium decreases the aluminum's density while increasing its stiffness. The industry is now developing this alloy for use with presently installed fabrication and assembly equipment.

Problems with inadequate fracture toughness—that is, resistance to the growth of small cracks—have delayed the introduction of such alloys. Boeing had hoped to use aluminum–lithium on its new 747-400, but the supplier couldn't meet the company's requirements. However, Alcoa now claims to have solved this problem through modified heat treatment, as well as by adding other alloying elements and cold-working the metal. Aluminum–lithium is a prime candidate for use on the 7J7 and Douglas's MD-94.

Several other changes in wing design offer fuel savings of about 10%. Computational aerodynamics, in which supercomputers are used to refine aircraft designs (HIGH TECHNOLOGY, April 1986, p. 62), now makes it possible to build a wing for

ON THE HORIZON: AN ECONOMICAL SST

As the next generation of subsonic airliners prepares for its commercial debut, promoters of a supersonic transport (SST) are selling anew the virtues of faster-than-sound airliners. In 1985, a report from the White House Office of Science and Technology Policy identified the SST as one of three goals for aeronautical research and development—alongside new subsonic aircraft and air-breathing flight-to-orbit craft. Early last year, Aérospatiale (Paris), which built the Concorde in collaboration with British Aerospace (London), unveiled a proposal for a 200-passenger Concorde II with a range of 5500 nautical miles and twice the fuel economy of the original Concorde. The major question is whether any new SST can avoid its predecessor's overwhelming marketing problems.

Boeing's Swihart sees a market for 500 SSTs.

The SST community has its eyes on transpacific flights, which remain grueling travel experiences. Durations of 14 to 15 hours are the norm on such routes as San Francisco–Hong Kong, Los Angeles–Sydney, Chicago–Seoul and New York–Tokyo. Imagine, then, the prospect of an SST that cuts transpacific flight time to four hours. "In the year 2000," says John Swihart, Boeing's vice-president for international affairs, "there will be 1400 747s in the world fleet. There will be 600 DC-10s and other long-range twin-engine widebodies. All of them will have the potential to be replaced. If you could come on the scene then with a suitable supersonic transport, you could easily project a market for 400 to 500 such aircraft."

Swihart points to three essential technical needs. First is a new class of "variable-cycle" jet engines, which will differ markedly from the Concorde's fuel-hungry variety. To obtain the extra thrust needed for supersonic speeds, the Concorde's engines contain afterburners, which add fuel to burn in the oxygen left over from the flow through the engine core. Since the extra fuel is very wasteful, the new SST engines will operate at temperatures and pressures high enough to obviate the need for afterburners. The engines will also incorporate fuel-saving fanjets for subsonic speeds.

Next come lightweight materials. Boeing would like to build an SST with temperature-resistant composites, but is not satisfied that acceptable versions are yet in sight. As an alternative that is closer to application, designers at Douglas and NASA/Langley tout superplastic titanium, a metal so malleable at high temperatures that sheets of it can be draped like cloth. Douglas engineers have devised a method of stacking such sheets together and bonding them to create metallic "sandwiches" thick enough and tough enough to form the wings and fuselage of an SST.

Finally, to minimize the drag that bedevils fuel economy, designers must produce smooth (or laminar) flow of air across the aircraft at supersonic speeds. Sucking in the air immediately adjacent to the aircraft surfaces could reduce drag by 80%, as well as help cool the aircraft. SST designers are exploring the use of tiny perforations in the aircraft's wings, a technique already under investigation for cutting drag in new subsonic airliners. NASA/Langley hopes to begin test flights of supersonic versions this year, with experimental panels mounted on F-15 and F-106 aircraft. Such systems might be ready by about 1995.

Given advances of these types, Boeing hopes that a next-generation SST would burn as little fuel as a 767 yet carry 400 passengers. By contrast, the Concorde burns as much fuel as a 747 but carries only about 100 passengers. A popular measure of airliner efficiency is seat-miles per gallon. The Concorde now gets 13 seat-miles; today's subsonic widebodies get as much as 75. The hope is that a next-generation SST in the year 2000 will reach at least 50, and perhaps 80. Even so, the craft will face stiff competition, for subsonic airliners of that era may get up to 150 seat-miles per gallon. Despite the cost-saving measures, then, passengers will have to pay a surcharge to travel on tomorrow's SSTs, just as they do for today's Concorde—which has largely failed to penetrate even the first-class market.

Another problem is purchase price. Because their speed makes SSTs potentially two to three times as productive as their subsonic counterparts, it will take only a third to a half as many aircraft to satisfy the market. To minimize its costs per seat-mile, a new SST must have a large passenger capacity—thereby reducing the number of markets it can serve and cutting the number of individual planes needed over any single route. As a result, the market will demand fewer SSTs, and the costs of development and production will be spread over fewer units, making an SST more expensive and hence less competitive. So the inevitable question arises: Will a next-generation SST be able to avoid the market experience of the Concorde, whose 11 aircraft in service contrast grimly with the 744 total orders for all versions of the Boeing 747?

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the Boeing 757 with a lift-to-drag ratio 12% better than that of the original wing of 1978. And "supercritical wings" developed by Richard Whitcomb of NASA's Langley Research Center (Hampton, Va.) avoid the increase in drag that occurs in normal wings traveling well below the speed of sound. The airflow on the typical wing's top surface speeds up and goes supersonic within a restricted region; it then slows down by passing through a shock wave, which causes the drag. The supercritical wing has a flattened upper surface that weakens this shock, and thus reduces the drag.

Whitcomb has also introduced small vertical protrusions at the wing tips, known as winglets. Flows of air around normal wing tips produce powerful vortices that roll off the wings and trail behind the airplane to great distances, carrying away energy and increasing drag. Winglets partially block and weaken the vortices, thereby improving fuel economy. They are incorporated in the new Boeing 747-400 as well as the Douglas MD-11, the new version of the DC-10 planned for introduction in 1990.

Another drag-reducing technology, under active development at both Douglas

and Lockheed (Burbank, Cal.), is intended to prevent the airflow over a wing from becoming turbulent just a short distance behind the leading edge. The method is to dot the wing's surface with millions of tiny perforations, drilled by electron beam. These suck in the air as it flows past, in effect drawing off the turbulent eddies. By doing so they create a smooth airflow not only in the region of the holes but for some distance downstream as well. Tests by NASA have shown that such limited regions of smooth flow can reduce fuel use by 12–15% for short flights, and by as much as 25% over longer ranges. Douglas may install such a system on its MD-94.

Inside the fuselage, the modern cockpit differs markedly from that of past aircraft. Cockpit interiors that were once festooned with every dial and gauge that might be necessary at any time in flight now feature video display screens that present only the information needed at any given time. Such instruments ease the crew's work load so effectively that the job of flight engineer has been eliminated in a number of new aircraft.

Boeing's 757 and 767 exemplify present-day cockpit instrumentation. The Federal Aviation Administration recently certified a flight-management system for those airliners that allows pilots to set their planes on automatic from takeoff to landing. The on-board computer determines the optimal flight paths, including climb and descent, and generates commands to the throttle as well as to the control surfaces. While it is most unlikely that any flight will proceed entirely by autopilot, such optimization would still give fuel savings of about 3%, and more on short flights; that could represent a $225,000 annual saving in fuel costs for a single 747-500.

The most frequently used instruments include a map display called the Horizontal Situation Indicator, built by Sperry (Phoenix), which shows airports, navigation aids, checkpoints along the route, and the aircraft's course. Prior to a flight, a pilot enters the flight plan with a keyboard resembling that of a hand-held calculator. During flight, the display overlays weather radar data on the navigation data showing flight plan and position.

A second video display, the Engine Indication and Crew Alerting System (EICAS), features two screens. The top screen displays each engine's main indicators: exhaust-gas temperature, rpm, and pressure. But the pilot can request additional engine parameters for display on the bottom screen, which normally remains blank. If a problem arises in flight, such as low oil pressure, a warning message flashes on the top screen while relevant data, such as engine oil readings, automatically appear on the bottom one. Flight crews thus see only the engine data they need, and only when needed.

Present-day versions of these instruments rely on CRT terminals. But the 7J7 is expected to introduce flat-panel displays that will be lighter and less bulky, in addition to having lower power and cooling requirements. Today's six-inch CRT screens are a foot deep and require a good deal of rack-mounted equipment. The move to flat panels will compress the electronics into integrated systems two inches deep, permitting larger panels and further simplifying the cockpit displays. At a cosmetic level, the concept could be extended to permit seat-mounted TVs for the passengers.

The next generation of airliners will also benefit from the current trend to fly-by-wire systems, which replace the traditional mechanical linkages between pilot and control surfaces with electronic signals. The Airbus 320 twin jet already uses controllers mounted beside the pilot's seat instead of the usual mechanical column mounted in front of the seat; the pilot grasps a hand grip that generates electronic commands to the elevators and ailerons. Fly-by-wire systems also incorporate the software-based equivalents of mechanical governors to ensure that pilots cannot stall the plane or impose loads beyond those its structure will bear. A pilot can go to full-up elevator in an emergency, confident that the fly-by-wire will prevent the aircraft from stalling or breaking up.

The two companies leading the way into the third generation of airliners are each taking markedly different approaches.

Boeing expects to extend this approach by installing a multiplexed data system known as DATAC (Digital Autonomous Terminal Access Communications) in its next-generation airliners. Today's data buses transmit in only one direction along a wire, and each sensor or instrument requires its own line. DATAC will string a single trunk line through the aircraft, with the individual instruments and sensors linked to it as if they were telephones. Each will have its own "telephone number" and will respond to a command only when it receives this identifying signal. This will allow large numbers of items to share the bus. Boeing expects that DATAC will save 46 miles or 1300 pounds of wire and 250 pounds of connectors. Within the electronics industry, Siliconix (Santa Clara, Cal.) has taken the lead in offering products of this type.

As planes shift to all-composite structures within the next few years, considerations of safety may force designers to supplement fly-by-wire systems with fly-by-light, based on fiber optic communications. Conventional aluminum airframes protect the plane's electronics very effectively from lightning, but all-composite airframes would require heavy shielding, which would reduce their weight advantage. Replacing part of the wire-based systems with optical fibers appears to be a better alternative. Douglas has been evaluating a fiber optic instrument—an aileron-position sensor—aboard a DC-10 recently delivered to Federal Express; it may install such systems extensively aboard the MD-94.

While their new aircraft show marked similarities in technology, the two companies leading the way into the third generation of airliners are taking notably different approaches to introducing that technology. Convinced that its 727 series had reached its technical limit, Boeing decided to build its replacement, the 7J7, entirely from scratch—replete with new engines, new materials, and new avionics—and sell it for $28 million in 1986 dollars, a price that aerospace analyst Wolfgang Demisch of First Boston (New York) describes as "very attractive." Douglas, lacking Boeing's financial resources, has opted for an incremental approach. It will move into the new generation basically by adding propfan engines to its present-day MD-80, which itself is an upgraded version of the workhorse DC-9. Douglas will then add more new technology to its next representative of the third generation, the MD-94. The 747-500, meanwhile, shows that even Boeing cannot always afford to design a new widebodied plane from the ground up. While incorporating ducted-fan technology, it will retain the basic airframe of its successful forerunners.

How will the airlines react to the third-generation aircraft? "If the engines do everything they're supposed to do, the airlines will accept them fairly readily," says Demisch. "I would guess that by the early 1990s there will be visions of much higher fuel prices, and new engines will look good." Airlines are not exactly enthralled with the idea of bringing back propellers, he notes, but the prospect of 40% reductions in fuel costs will likely be too good to resist. □

T. A. Heppenheimer, a freelance writer based in Fountain Valley, Cal., has a PhD in aerospace engineering.

For further information see RESOURCES, *p. 65.*

MANUFACTURERS MOVE TOWARD COMPUTER INTEGRATION

Automated datalinks are improving communication between design and production, management and shop floor, and even factory and supplier

BY JEFFREY ZYGMONT

American manufacturers are generally perceived to have fallen behind the times, largely failing to exploit the abundant high technology resources of their own country in order to stay competitive. But a cadre of forward-looking U.S. companies are systematically deploying computers—both in machine control and in data processing—to orchestrate flows of data, throughout their operation, in support of manufacturing. Such "computer-integrated manufacturing" (CIM) is not a single technology but a global concept, encompassing nearly all efforts to streamline a company's manufacturing and support activities. It may mean, for example, tying together product design departments and production engineering so that the same product data created on a computer-aided design (CAD) system are also used to program computer-controlled machine tools to cut the parts. Or it may entail automatic communication between control computers in the factory, so that production is smooth and coordinated.

Because no two manufacturers have the same needs, says John J. Clancy, president of McDonnell Douglas Manufacturing Industry Systems (St. Louis), "CIM solutions are not generic; they have to be tailored to individual companies." A manufacturer's approach to CIM depends on such variables as its size, the age and number of its facilities, the volumes and varieties of its products, the kinds of arrangements it has with vendors, and the changeability of its market, to cite a few.

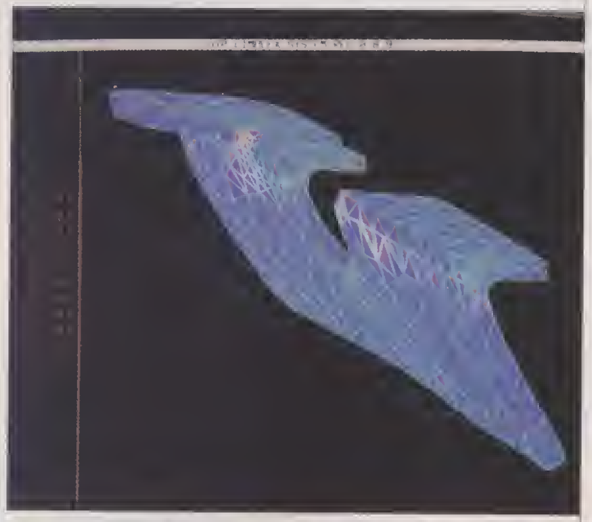
Nevertheless, three distinct strategies for implementing CIM are emerging, says Peter Marks, vice-president of Automation Technology Products (Campbell, Cal.), a supplier of computer-aided design and manufacturing (CAD/CAM) systems. One approach is to integrate *inside to outside*, creating a computer network for data exchange between a manufacturer and its suppliers and/or customers. A company may also integrate from *beginning to end* of a product's development cycle, creating a data continuum from earliest design and planning through engineering and production, and even tying in support departments like marketing and technical publication (to aid in the preparation of operator manuals and repair guides). Finally, a company may decide to integrate from *top to bottom* in order to disseminate information downward for better control of manufacturing operations and to feed information upward from the shop floor for use in business management and planning.

The inside-to-outside approach is often adopted when the main goal is better service to a manufacturer's customers. For instance, TRW's Automotive Worldwide Sector (Cleveland) is implementing an electronic order-entry system that automatically logs orders for parts from automakers, speeding up the process considerably. So far, direct order entry occurs only between TRW's Rogersville, Tenn., plant and Chrysler's minivan assembly facility in Windsor, Ontario. To enable Rogersville to pace its output and delivery of rack-and-pinion steering assemblies, Chrysler electronically transmits its production schedules to the TRW plant.

Charles T. Smith, director of information services for the TRW sector, explains that the company is instituting similar systems with other major customers—at the request of the automakers themselves. But progress is slow because each company has a different computer system that must interface with TRW's. Currently, says Smith, the Automotive Industry Action Group, a cooperative trade organization, is working on an industrywide communication standard.

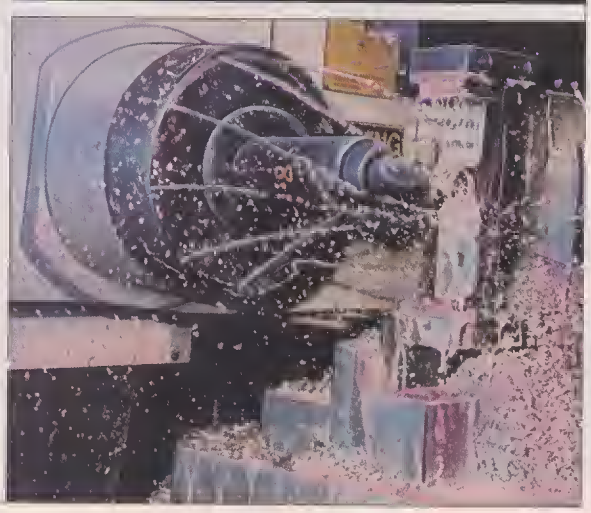
ILLUSTRATION BY PAUL MOCK

CIM is not a technology, but a way of organizing manufacturing technologies for a smoother flow of information, greater efficiency, and faster product development. Therefore CIM strategies vary widely between companies.



Integration of design and production at Vought Aero Products (Dallas) starts with computer-aided design of a B-1B bomber spar clip (which joins aircraft skin to ribs). Pink areas are stress points identified by finite element analysis.

Using the same database, manufacturing engineers simulate the machining of the part to determine what cutting tools to use. Then they develop a computer numerical control (CNC) program for a machine tool to make the part. The CNC program is uploaded to the company's management database.



The main database transmits the CNC program to the computer controlling the flexible machining cell, which then assigns a specific machine tool, pulls material from inventory, and schedules the job. The software responsible for the data transactions is Automation Technology Products' Factory Automation Information Management system.

The jet engine maker Pratt & Whitney (East Hartford, Conn.) is the hub of a two-way product data exchange, accessing digital product descriptions from some of its customers—most notably Boeing Commerical Airplane (Seattle)—and making its own database available to about 150 of its subcontractors. But Richard Lopatka, manager of CIM technology, explains that even Pratt's highly automated engineering department, which relies heavily on CAD/CAM internally, must print paper drawings for departments, companies, and agencies that don't have the technological capability to receive electronic versions. "We cannot get to a wholly electronic environment until all the partners involved have terminals," he says.

A major barrier to exchanging product description data is the lack of a common computer language that permits comprehensive communication among the many different hardware and software systems in use. Part of this issue has already been addressed by IEEE's Initial Graphics Exchange Specification (IGES), a data standard for communicating geometric product information between computers. Major CAD/CAM vendors subscribe to the IGES standard so their systems can share data with others. But IGES doesn't cover nongeometric data like tolerances, which are also part of a complete product description. The proposed solution is a different standard, the more thorough Product Data Exchange Specification (PDES), which is being drawn up by the National Bureau of Standards. A first draft is expected in April.

Product definition models are usually crucial to the CIM strategies of companies working toward beginning-to-end integration. Here communication standards like IGES and PDES are also important, but they may be worked around more easily, since a company can limit its equipment selection to compatible systems, or write proprietary software for communication between departments. Therefore it's not surprising that efforts toward integration within a company have progressed the farthest. At Rockwell International's Rocketdyne division (Canoga Park, Cal.), integration around a common product database is six years old and still evolving, reports division president Richard Schwartz. This year the division plans to link its coordinate measuring machines—quality-inspection devices that measure manufactured parts—with its CAD/CAM system. What's more, Rocketdyne is working with the Milwaukee automation-control company Allen Bradley on a distributed data link between Rocketdyne's CAD/CAM departments and shop-floor

machine tools, so that part-cutting programs will flow directly from the computer on which they're generated to the machine tool that will apply them. Currently, part descriptions are downloaded from CAD to a separate computer, which converts them into cutting instructions and then puts the program onto a special tape that's read by machine tool control computers.

Another aspect of beginning-to-end integration involves tying together operations on the factory floor. A celebrated example of this is Deere & Co.'s tractor works in Waterloo, Ia., which makes a wide variety of farm tractors in sequences that change each day, according to orders received. Integration is achieved under an IBM mainframe computer, the system's host, which directs nine Digital Equipment minicomputers controlling operations in the four-building facility. Each night, the host tells minicomputers controlling automated high-rise storage systems what parts to withdraw for the coming day's production. Other minicomputers that control manufacturing operations are given the day's "build" orders, so they know what tractors they must make and in what sequence.

"What is really happening, therefore, is that the host computer is running the business just as it does in traditional manufacturing environments," says Deere's William G. Rankin, manager of CIM services. "The difference is that it is telling minicomputers instead of people what output is expected from them each day."

In addition to talking to the IBM host, minicomputers may also transmit messages requesting parts from other minis, says Rankin. For instance, when a storage-system controller withdraws an engine and transmission, it tells the computer in charge of tractor assembly that the components are on their way. The assembly system mini may then request the appropriate tractor cab from a third minicomputer controlling another automated storage system. That computer, in turn, confirms the request if the part is available. If it's not, the tractor assembly controller will not build the tractor, since the missing component would cause a costly production delay and possibly tie up the entire assembly line. Since such decisions are made at the shop-floor level, Waterloo's minicomputers also communicate upward to the mainframe, both to report such changes in scheduling and to update the host computer's master inventory records.

Although Deere's Waterloo CIM system integrates each tractor's production from beginning to end, the upward and downward flow of information puts it in the category of top-to-bottom integration as well. Management directives—the build orders—move downward on the data continuum. Status reports—parts used—flow upward.

TRW's Rogersville steering assembly plant uses an inside-to-outside order-entry system, but the CIM strategy within the facility is decidedly top-to-bottom. It gives workers greater decisionmaking authority in an effort to improve quality and reduce cost at manufacturing's most fundamental level, the factory floor. Rogersville's Work Center Information System—scheduled to go into operation this year, following a 2½-year phase-in period dedicated mainly to worker training—consists of personal computers at each work cell, tied together in a local-area network. Since communication is the system's main goal, TRW stuck largely with hardware from a single vendor—in this case IBM—to avoid compatibility problems that often arise when too many computer types are used in a single system, explains information services director Smith.

CIM is spawning new, factory-hardened computer equipment like Hewlett-Packard's 9666A terminal in a sealed case.

The system gives each operator the information needed to run the station as if it were a small business. Desktop computers display each workstation's daily output requirements; then it's up to each station operator to select the material and tools to get the jobs done, and set up the best sequence for making the needed parts. To

Pratt & Whitney's Richard Lopatka is recruiting a larger staff of manufacturing engineers to put CIM into action.

JACK SPRATT

BUSINESS OUTLOOK

THE SEGMENTED CIM MARKET

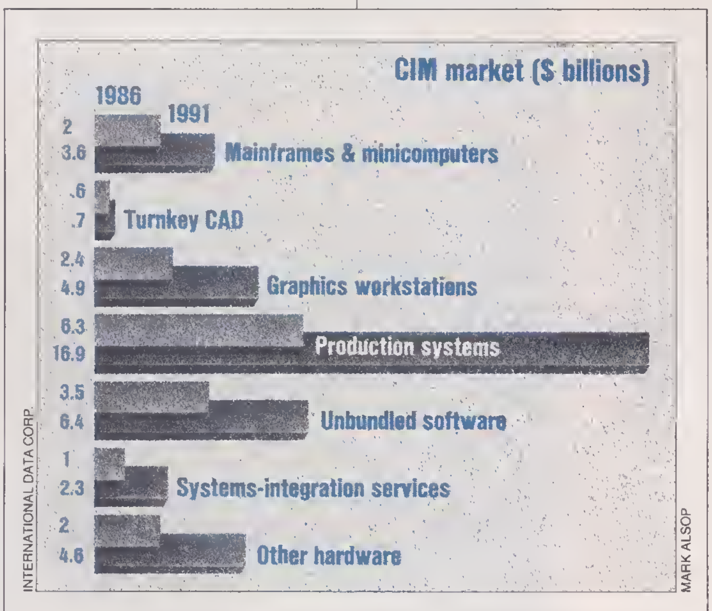
Computer-integrated manufacturing (CIM) translates into a diverse array of technologies and services provided by numerous specialty vendors, none of which dominates the field. "Since all manufacturers are different," says Michael Seely, senior industry analyst with Dataquest (Cupertino, Cal.), "every CIM installation must be a customized system."

Certain vendors, however, exert considerable influence within the major CIM building-block areas. The following product categories have at present a total market value of $17.8 billion, according to IDC/CIMdata (Framingham, Mass.); that figure should rise to $39.3 billion by 1991.

• *Mainframes and minicomputers* serve as central control units for factory-floor operations and perform related data-processing functions. Such hardware comes principally from the computer giants IBM (Armonk, N.Y.), Digital Equipment (Maynard, Mass.), Control Data (Minneapolis), Data General (Westboro, Mass.), and Prime (Natick, Mass.).

• *Turnkey computer-aided design systems* are dedicated to mechanical design tasks such as drawing and geometric analysis. CAD hardware and software are available from Computervision (Bedford, Mass.), Calma (Milpitas, Cal.), Applicon (Ann Arbor, Mich.), Intergraph (Huntsville, Ala.), and McDonnell Douglas (St. Louis), among others.

• *Graphics workstations* are used in customized CAD/CAM systems. Principal vendors include Sun (Mountain View, Cal.), Apollo (Chelmsford, Mass.), Tektronix (Beaverton, Ore.), Calcomp (Anaheim, Cal.), and Hewlett-Packard (Palo Alto, Cal.).



• *Production systems* do shop-floor work and include robots from such firms as Asea (White Plains, N.Y.) and Unimation (Danbury, Conn.). Among suppliers of numerically controlled machines are Cincinnati Milacron (Cincinnati) and Kearney & Trecker (Bloomfield Hills, Mich.). And materials-handling equipment is produced by Litton Industries (Beverly Hills, Cal.) and Eaton (Cleveland).

• *Unbundled software* is purchased separately for specific tasks such as engineering, manufacturing resource planning, production support, and process planning. Comserv (Eagan, Minn.), Management Science America (MSA—Atlanta), and Honeywell (Minneapolis) are some of the major vendors.

• *Systems-integration services* are provided by such firms as Electronic Data Systems (Dallas), General Electric (Fairfield, Conn.), Computer Sciences (El Segundo, Cal.), and Allen-Bradley (Milwaukee).

• *Other hardware* required in CIM systems includes a wide range of sensors and actuators used to establish the location and status of shop-floor components. Such equipment is available from Cutler Hammer (Milwaukee), Honeywell (Fort Washington, Penn.), and Micro Switch (Freeport, Ill.), among others.

Of all these segments, IDC projects the most dramatic growth in production systems, with revenues rising from $6.3 billion to $16.9 billion. Not all industry observers, however, share this view. "Manufacturers have bought considerable amounts of hardware recently because of favorable investment-tax credits for plant modernization," notes Dennis Vohs, MSA's president. "With the new tax law, these benefits are greatly reduced." The result, he adds, is that forecasts based on projections of recent behavior may be overly optimistic.

Sales in computer-integrated manufacturing generally have not lived up to early 1980s expectations. "A growing number of firms are implementing CIM, typically in an incremental fashion at the department level," says Allan Christman, general manager of CIM at Control Data. "However, 65% of the dollars spent in CIM come from large, complex systems purchased by the top 2% of manufacturers." Growth in this segment has been slowing down, he points out, as companies take more time to justify and evaluate their needs for major installations.

Another roadblock to implementation is the lack of data communication standards for shop-floor equipment. The Manufacturing Automation Protocol (MAP), initiated by General Motors, attempts to link together such production areas as order entry, inventory control, robotics, numerically controlled machining, and inspection. However, "since standards are not yet clearly defined, not that many MAP-based products are currently on the market," says Alice Greene, consultant with Arthur D. Little (Cambridge, Mass.).

But Christman believes that long-term prospects for CIM are favorable. "Faced with lower manufacturing costs abroad," he says, "a growing number of U.S. manufacturers realize that they must implement CIM not only to remain competitive, but simply to survive." □ —***John K. Krouse***

assist with these decisions, the information system provides such data as the costs of available materials.

TRW's investment in training underscores the importance of personnel in computer integration. "The failure of new systems is much more psychologically based than technologically based," says George J. Hess, vice-president of Ingersoll Milling Machine (Rockford, Ill.). "We can change that dramatically by more effective training."

On a more basic level, manufacturers experienced in CIM emphasize the need to ease employees through the transition from a company's former operating procedures. To unite an array of independent computer systems with CIM, says Philip N. Condit, president of Boeing Commercial Airplane, "a lot of classical boundaries have to be violated. And when that happens, the cultural impact can be severe." To forestall turf wars, Boeing uses product teams; key personnel from departments encompassing product design, engineering, production, and support are brought together from the outset of a program to foster communication and a unified effort.

Another way to ease conflicts is to build solutions into the computer systems themselves. Northern Telecom is taking this approach with its Engineering Change Manager, an expert system that is expected to become operational later this year. Andrew Young, the telecommunications company's director of new-product introduction, who has spearheaded the company's CIM efforts, explains that a manufacturing engineer may often want to change the design of a part so it can be produced more easily.

At Northern Telecom's Santa Clara, Cal., facility, for example, machines that assemble printed circuit boards may have a hard time placing a component at the coordinates designated for it. Yet the manufacturing engineer cannot unilaterally modify component placement without the risk of changing the performance characteristics of the entire printed circuit board. Thus the Engineering Change Manager expedites both a request for a change and its approval. Young says the system cuts about 75% of the time needed for an engineering change by getting messages to the computer terminals of the appropriate parties automatically. An expert system is needed to handle the request's routing, since this is an organizational procedure that does not follow a strict logical sequence. Instead, the routing depends on rules that may vary according to such factors as the urgency of the request, the severity of the change, and the origin of the part under consideration.

Other artificial intelligence systems for CIM are being developed as well, to handle the infinitely variable problems that can combine to prohibit the smooth flow of manufacturing: parts not arriving when or where they're supposed to, equipment breaking down, workers calling in sick, to name only a few. For example, the AI system supplier Carnegie Group (Pittsburgh) has developed "dynamic scheduling" software that takes over to fulfill the demands of a company's master production schedule. It schedules work for individual tools and stations, controls the delivery of material to workstations, and tracks work in process. It constantly monitors and reschedules work at each interruption, keeping equipment utilized to the fullest.

Since it brings needed flexibility to the computer control of manufacturing, AI will play an increasing role in CIM, says Geisel. Last year, sales of artificial intelligence systems for manufacturing were about $160 million, or a third of the total AI market, he says, and industry spent twice that amount in developing its own systems.


EDDIE SHVARTZMAN

Northern Telecom's Andrew Young developed a corporate-wide strategy for smooth integration.

With or without AI, the best way to make the transition from a conventional, compartmentalized manufacturing operation to an integrated one, say most CIM analysts, is to break up the undertaking into small, manageable pieces. For many manufacturers that are unable to commit vast sums to new equipment, an effective CIM strategy may require little more than creating an atmosphere that encourages integration. This may mean gradually building a common computer architecture by selecting equipment from one or just a few suppliers, even when it's purchased to be used in isolation, says Donald Jenkins, CIM product marketing manager for Digital Equipment (Marlboro, Mass.). Later, when a company is ready to integrate, it will encounter fewer compatibility problems.

CIM is highly amenable to this approach, according to Donald I. Manor, manager of Deere's Design Systems division, because it is generally being pursued by top corporate managers, who can coordinate automation purchases. Such high-level direction demonstrates that CIM is not just another automated system but a whole new way of looking at automation. "CIM is not technology," says Clancy at McDonnell Douglas. "It is a way of *using* technology. It is a totally new way of planning and managing the manufacturing process."

Thus, even a less-than-complete transformation can show discernible results in cutting costs, improving quality, and responding to rapid changes in technology and markets. For example, Deere found that the data communication network at its Waterloo plant cut overall work-in-process inventory in half; costly raw-steel supplies are now at a sixth of their previous level. At Ingersoll Milling Machine, computer integration imposed order on an unwieldy software collection consisting of 1300 different programs, feeding on 225 different databases that were chock-full of redundant and uncoordinated information. "We realized that we simply could not continue down that road, so we reprogrammed our existing systems into a completely integrated corporate database system," says Hess. "The payoff of integration," says Automation Technology's Marks, "is to make networks of knowledge, workers, and production systems respond with the flexibility of nimble organizations." □

Jeffrey Zygmont is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 65.*


USER
CONTROL
INTERFACE
DATAPATH
DATA
UNIT
IBM CONNEC


Meridian* business services add more to Centrex.
Today, you can choose from a whole supermarket of data services through the public telephone network. Act now and be ready for a future where sharing data, text and image will be as easy as using the phone.
northern telecom
COAX ELIMINATION
DATA ABOVE VOICE
meridian
NETWORKING

ENERGY-WISE BUILDINGS

Innovative ways to cut costs include windows that switch from light to dark and materials that store heat for later use

BY HERB BRODY

In recent years, plunging oil prices have muted concern over energy, and "conservation," with its ascetic connotation, has fallen out of favor. But seeds of frugality planted during the oil shocks of the '70s are bearing fruit in the form of new technologies that promise all the financial benefits of reduced energy consumption without sacrificing comfort or convenience.

Among the juiciest targets for efficiency measures are buildings: more than a third of the country's energy, including over 60% of its electricity, goes toward heating, cooling, and lighting. Obviously, curtailing this consumption would shrink energy bills. But the incentive to save rests not just with the user of energy, but with the provider as well. Enlightened utilities increasingly view efficiency as another "source" of power; it's often cheaper to buy efficiency—say, by subsidizing the installation of weatherstripping—than to build additional generating capacity that may stand idle if demand fails to rise according to projections. The risk of excess capacity reflects the uncertainty over how much energy will be needed in the future; forecasts on the rate of increase in electrical demand through 1990, for example, range from 1.5 to 4.5% per year, according to Peter Blair, manager of energy and materials programs at the congressional Office of Technology Assessment.

Buildings can, and do, achieve significant efficiency gains with such simple measures as installing double-glazed windows, insulating walls and roofs, and plugging up holes. This approach is "like putting an overcoat on the building," says David Pellish, who heads the U.S. Department of Energy's solar buildings program. Now, he says, it is becoming possible instead to turn the building envelope into a "controllable membrane," letting light and heat in and out precisely as desired. Here are some of the most important innovations:

- Windows with sophisticated coatings that bottle heat inside during the winter and keep sunlight at bay during the summer.
- "Phase-change materials" that store and release large volumes of heat, stabilizing room temperature almost as if the building were underground.
- Switchable windows that can be electronically darkened and lightened to match the energy needs of the moment.
- Plastic pipes and holographic coatings that bring sunlight deep into a building's interior, reducing the need for artificial lighting.
- "Superinsulated" houses so snug that they can be heated by the warmth of bodies, light bulbs, and appliances.

Typical buildings squander energy most heavily through their windows; the amount of energy lost this way in the U.S. each year is equivalent to the entire output of the Alaska pipeline. But a new breed of windows with a feature called low emissivity is starting to plug this enormous leak. Introduced commercially in 1983, low-emissivity windows are capturing a growing share of the commercial and residential building market. By 1990, according to several estimates, half the residential windows sold will be of this type. "Low-e" glass is made commercially by several major glass companies, including Pittsburgh Plate Glass, AFG Industries (Kingsport, Tenn.), Cardinal IG (Minneapolis), and Ford Glass (a Dearborn, Mich., division of Ford Motor).

Standard insulating windows consist of two panes separated by an air gap, typically half an inch. In a low-e window, the inner surface of one of these panes is coated with a thin film consisting of multiple layers of metal or metal oxide, or both. The coating, typically only a few hundred atoms thick, is transparent to the sun's light and heat but does not transmit the long-wavelength infrared radiation that is


ROGER RESSMEYER

emitted by warm indoor objects.

The infrared given off by anything in the room—a person, say, or a piece of sun-warmed furniture—is absorbed by the window's inner pane, which heats up. In an ordinary window, this heat is radiated across the air gap to the outer pane, whence it is lost to the outdoors. But a low-e coating applied to the air-gap surface of the inside pane stymies heat radiation across the gap. Unable to escape via its normal route, heat builds up in this glass pane, eventually being radiated back into the room. In effect, the low-e window traps heat indoors, providing the same insulating value as would a third pane of glass. (Triple-glazed windows are available but seldom used, because of high cost and weight, as well as reduced clarity.)

The first generation of low-e glass suffers from one big problem: the vacuum-deposited coating is extremely fragile. Until the glass is sealed into a double-glazed insulating window unit, it demands careful (and expensive) handling procedures in order to protect it against touch and atmospheric exposure. But several major glass companies have recently started using a different technique that makes more rugged low-e coatings. In this "pyrolytic" process, low-e materials are infused into the glass sheet while it is still partly molten; the glass hardens with a built-in low-e surface that can then be used in unprotected applications such as storm windows.

Sandwiching a coated plastic film between panes of an insulating window helps keep heat indoors. A fourth of residential windows sold this year will use such "low-emissivity" coatings, says Alex Tennant, VP of Southwall Technologies, which pioneered the technology.

Low-e glass is intended mainly to keep buildings warm. But as long as the window is shaded from direct sunlight, the low-e effect can be helpful in summer as well as winter. The heat lapping at the window takes the form of long-wavelength infrared radiated by hot asphalt, cars, buildings, and so on; the low-e window throws such radiation back outside in the same way that it reflects interior heat inside. Still, for the Sun Belt, glassmakers typically combine low-e coatings with reflective or tinted glass, which reduces direct solar heat.

The ideal, of course, would be a clear glass combining low-e properties (to aid wintertime heating) with solar heat rejection (to lessen the air conditioning load during the summer). Southwall Technologies (Palo Alto, Cal.), whose Heat Mirror was the first commercial low-e window, is moving in that direction. Southwall has tuned its proprietary low-e coating to reflect the sun's heat—that is, near-infrared radiation—while transmitting most of the visible light. Thus the window rejects heat from direct sunlight as well as from hot outside objects.

Southwall's windows differ from other low-e offerings in that the coating is not on the glass itself but on a thin polyester membrane spaced halfway between the

two panes. This design adds a second air space for more insulation. And from a production standpoint, the flexible plastic film is easier to handle than glass plates.

The low-e coating boosts a double-pane window's insulating value by about 50%, from R-2 to R-3 (R is the standard index of thermal resistance, with higher numbers signifying better insulators). But a more drastic improvement could come from a new transparent material under development.

"Aerogel" has an insulating value of R-20 per inch of thickness, according to Arlon Hunt, leader of the microstructured materials group at Lawrence Berkeley National Laboratory (Berkeley, Cal.). Thus a half-inch-thick slab of aerogel (at R-10), sandwiched in stiff plastic or glass for structural rigidity, bottles heat five times as efficiently as a conventional double-pane window, and three times as well as a low-e window. This performance arises from the material's structure; particles of pure silica hook together to form cavities only a few nanometers (billionths of a meter) in diameter. These tiny holes trap and isolate air molecules, preventing them from transferring thermal energy to other molecules. And because the pores are much smaller than visible light waves, aerogel is clear—one of the few known materials that are both transparent and porous. Hunt has formed a company, Quantum Optics (Emeryville, Cal.), to produce aerogel commercially. He expects to begin pilot production in about two years, with full-scale manufacturing by 1990.

A further boon to energy efficiency would be a window that could be switched on and off like an appliance; it could be made transparent to let in all the scarce winter light, and then darkened against the searing summer rays. One way to accomplish this would be with photochromic materials, such as silver chloride, which become darker in response to bright light. While popular for sunglasses, photochromics would have the drawback of blocking the sun on cold, bright days.

A more flexible technology is electrochromics. An electrochromic window is coated with special materials in multiple layers to yield two electrodes sandwiching a conductive electrolyte. In the absence of electric current, both electrodes are transparent. But application of a voltage forces some of the electrolyte's ions into the crystal lattice of one of the electrodes; in this altered state, the material turns less transparent. Reversing the voltage extracts the ions from the electrode, leaving it clear again. The process can be reversed millions of times, according to David Rauh, vice-president and research director at EIC Laboratories (Norwood, Mass.), which is working on electrochromic technology for the U.S. Department of Energy.

In one of the best-known electrochromic reactions, tungsten trioxide (WO_3) serves as the active electrode. WO_3 turns from clear to deep blue when infiltrated with lithium ions from the electrolyte (lithium aluminum fluoride). When the current is reversed, the ions migrate to the opposite electrode. To increase the on/off contrast, this counterelectrode can be made of an electrochromic material, such as iridium oxide, that behaves in a fashion complementary to WO_3—that is, becoming *more* transparent with the absorption of ions. That way, as the ions shuttle back and forth, the electrodes work in concert, both turning dark when the ions reside in the WO_3. Small laboratory units with the tungsten/iridium combination have transmitted 68% of visible light when on, switching to less than 10% when off, says Rauh.

One problem with existing electrochromic materials such as WO_3, however, is that, when off, they block both light and heat; such a window could keep a building cool only by keeping it dark as well. In these devices, the WO_3 is in amorphous (disordered) form. But a more selective kind of electrochromic material under development, using crystalline WO_3, admits the sun's visible light while screening out the infrared rays that bring heat. In the absence of ions, the crystalline WO_3 transmits both visible light and the near-infrared component of solar radiation. At higher ion concentrations, the material reflects the near-infrared while transmitting visible light. At still higher ion levels, the film turns reflective across the entire spectrum.

Holograms and light pipes could bring daylight deep into building interiors, reducing the need for artificial illumination.

Such a window could thus be electronically "tuned" to match changing energy needs. It is possible, for example, to connect the window's input to a thermostat; rising temperature could trigger a voltage that would cause the window to become reflective over a broader swath of the near-infrared spectrum, preventing further (unwanted) heating.

Switchable windows probably will not be ready for buildings until the '90s. "This is Buck Rogers stuff," says Rick Cunningham, executive vice-president of AFG Industries. But the technology may debut sooner in automobiles. In 1985, Nissan Motors showed a prototype car—the Cue-X—whose assortment of advanced technologies included an electrochromic sunroof. The amount of light admitted by the roof could be set anywhere between 5% and 30%. Nissan has no plans to market the Cue-X itself, but says that its features are "slated for introduction on Nissan's cars of the near future."

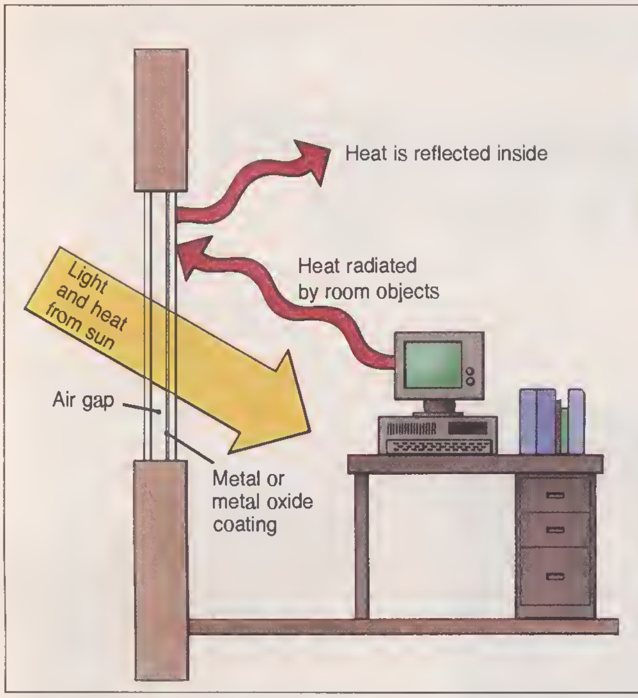
Commercial buildings can use as much energy for lighting as for heating and cooling. Most offices depend largely on artificial illumination because the natural light entering through windows covers only a thin perimeter of floor space. Innovative techniques for bringing daylight indoors could cut this energy burden substantially. In addition to reducing the power needed for lighting fixtures, daylighting technology also cuts down on the air conditioning load: every light bulb, after all, is a heater too.

In one of the most advanced demonstrations of new daylighting technology, the entire top floor of one of Toronto's new Victoria Park buildings—an area of about 20,000 square feet—is lit in part with "light pipes." These acrylic tubes, developed by TIR Systems (Burnaby, B.C.), distribute sunlight that has been collected and focused by rooftop mirrors. Concentrated sunlight is funneled through a short vertical section of pipe and then split up to fill a network of ceiling-hung pipes. They look like glowing fluorescent tubes, except the color is more natural. The system requires direct sunlight; when it's cloudy or dark out, auxiliary electric lights turn on automatically.

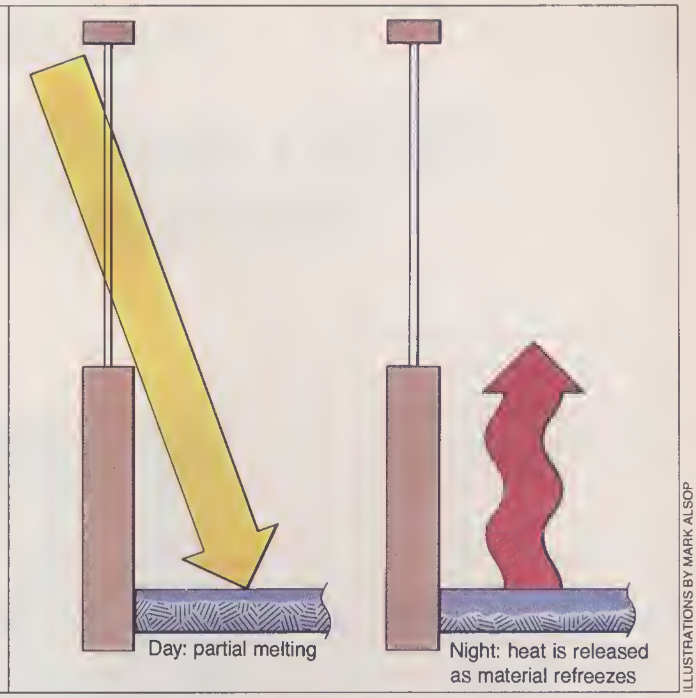
Light travels through the pipe by multiple reflections off a finely corrugated inner wall. At each point of reflection, a small fraction of the light leaks out; the accumulation of these escaping rays provides diffuse illumination. Some 50–80% of the sunlight entering the pipe winds up as useful room light. (Lorne A. Whitehead, who founded TIR in 1983, invented the light pipe while a graduate student at the University of British Columbia in Vancouver, to bring sunshine into his dim basement laboratory.)

The Victoria Park installation, supported by the National Research Council of Canada, is intended to demonstrate the feasibility of light pipes for solar illumination. The technology is not untested, however; TIR has already supplied similar optical conduits to more than 150 buildings for distributing artificial light (typically to illuminate chemical-storage rooms in which electrical fixtures could spark an explosion).

Crucial to a light pipe's operation are optical elements that track and focus the sun's rays. At present, this task requires large, motor-driven mirrors that are prac-



Low-emissivity windows work as heat mirrors. An ultrathin coating is usually applied to the air-gap surface of a double-glazed window's interior pane. As room heat warms the pane, the low-e surface—which is a poor heat radiator—reflects the heat back inside.



Phase-change materials such as certain waxes and salts can be incorporated into building materials to keep indoor temperature steady. During a winter day, for example, the material stores solar heat by melting; at night this heat is liberated as the material refreezes. With a sufficient volume of material, the building will stabilize at the phase-change temperature, much as a glass of ice water stays at 32° F.

tical only for rooftops, limiting the piping of daylight to a building's uppermost stories. Another innovative technology may allow the sun to shine in other areas as well.

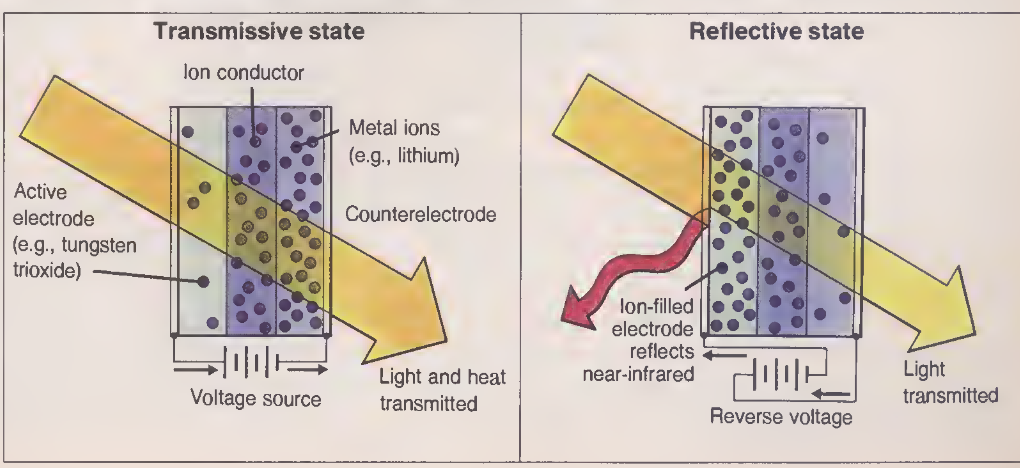
Holographic optical elements—diffractive components that are thin and light enough to mount on windows—can, without moving, track the sun across the sky and deflect its rays to a wall- or ceiling-mounted diffusion panel to illuminate interior space. The idea, being developed under contract to the Department of Energy by Advanced Environmental Research Group (AERG) in Cambridge, Mass., depends on a hologram's ability to act upon a beam of light in ways impossible with ordinary lenses and mirrors.

Holograms are made by intersecting two laser beams and recording the resulting interference pattern (closely spaced bands of light and dark) in a photosensitive medium. Light striking the finished hologram is deflected in a direction that depends on the relative angles of the two laser beams. It's possible to "program" a hologram during its fabrication so that it will focus light striking over a particular range of input angles into any desired output angle. Thus a properly made holographic element could deflect a morning ray of sun coming from low in the eastern sky to the same approximate place as a mid-afternoon beam from the west.

The problem now being attacked, according to AERG project director Richard Ian, is control of color. Holograms behave somewhat like prisms, breaking up the incoming white light into its component hues. Thus the hologram may bathe some areas of a room in red light, others in blue; if the colors are not as widely separated, rainbow patterns will show up, an effect that can be disconcerting in an office.

In addition to better windows and innovative daylighting, another way to cut energy consumption is with building materials that retain large amounts of ther-

An electrochromic window could be electronically switched to block unwanted solar radiation. Applying a voltage in one direction pushes metal ions into the active electrode layer, causing it to reflect the sun's heat while remaining clear to visible light. Reversing the voltage shuttles the ions into the opposite electrode, restoring transparency.



BUSINESS OUTLOOK

ENERGY MANAGEMENT MARKET CONTINUES TO HEAT UP

Companies that make automated systems for controlling energy use in commercial buildings have excellent prospects despite falling energy prices. Whereas in 1974 there were fewer than 10 suppliers of energy management systems (EMS), the industry now has more than 200, according to the Electric Power Research Institute (Palo Alto, Cal.). The current EMS market is worth an estimated $2.5 billion a year, according to Booz, Allen & Hamilton (New York), and is growing at about 10% a year.

Honeywell (Minneapolis), Johnson Controls (Milwaukee), and MCC Powers (Northbrook, Ill.) dominate the market, followed by such major players as Andover Controls (Andover, Mass.), Barber-Colman (Rockford, Ill.), Robertshaw Controls (Richmond, Va.), Butler Controls (Redmond, Wash.), American Auto-Matrix (Export, Pa.), and Staefa Control System (San Diego).

Over the past 10 years, energy control technology has evolved from simple mechanical systems to complex networks of sensors and computer-regulated electronic controls. Heating, air conditioning, and lighting can be precisely adjusted according to preprogrammed routines or in response to such data as temperature, airflow, or angle and intensity of sunlight. Such electronic systems require little maintenance and are less costly to install than the traditional pneumatic systems, which use copper pipe carrying compressed air to actuate valves and vents.

"A handful of pneumatic-systems companies traditionally dominated the industry, but because they were slow to see the potential of electronic systems, new players like ourselves had a niche in which to grow."

Dale Bunce, Marketing VP, Staefa Control System

"With the new control systems and the appropriate access code, you can use the telephone to dial in your own temperature setting and lighting level."

John Petze, Manager of Technical Support, Andover Controls

Along with direct sale and leasing, many suppliers use creative financing to sell their control systems, including an arrangement in which the building owner and the equipment supplier share the savings. Johnson Controls, for example, installed a control system in two 22-story office buildings in Boston owned by the Massachusetts state government. The company put up the capital, operates the system, and guarantees a $1.1 million annual saving, half of which goes to the company to pay back its original investment plus profit (the other half goes to the state).

Industry observers agree that lower energy prices do not threaten EMS market growth, because control systems now do more than simply manage energy use. Many control companies emphasize the advantages of complete building automation, including security, fire monitoring, and voice and data telecommunications. For example, a new hotel in Phoenix operated by the Crescent Hotels Group features energy management systems from Andover (for common areas) and Robertshaw (for guest rooms). Both systems regulate heating and cooling and watch for fires, while an electronic security system from Marlok (Sunnyvale, Cal.) controls room access. All are linked to a Honeywell system at the front desk that, among other things, records arrivals and departures and monitors guests' expenses.

U.S. firms, however, face emerging competition from Japanese manufacturers of heating, ventilating, and air conditioning (HVAC) equipment and control systems. Mitsubishi, Hitachi, Sanyo, and Toshiba, among others, have already established themselves in the U.S. residential HVAC equipment market on the strength of lower cost and higher quality, according to Robert Thompson, marketing VP at American Auto-Matrix, and some of them are expected to move into the commercial building controls market as well.

Another problem facing U.S. control companies is a decline in new building construction. "The construction business is cyclical," says Robert Milburn, marketing VP at MCC Powers. "We're now going into a period—the next three or four years—when construction will be flat or contracting." But there are other opportunities. As EMS prices fall, the systems become more feasible for buildings of less than 50,000 square feet. And during slow construction periods, control companies can concentrate more on retrofitting existing buildings with state-of-the-art energy management systems. □ ***—Richard J. Myers***

Timing's The Thing

Efficient use of energy sometimes involves not just quantity but timing. For years, utilities have tried to redistribute demand by charging more during peak hours. Recently, they have been taking more active approaches.

"Load management" programs being tried in several areas, for example, allow the power company to shut off certain home appliances during hours of peak demand. The largest load management experiment, inaugurated this winter by Florida Power & Light (Miami), will involve 10,000 customers in Dade County by the end of 1987. The utility hooks up electronically activated controllers to appliances such as water heaters, air conditioners, and swimming-pool pumps at the homes of volunteer customers (they receive a rebate for participating). During peak hours, signals go out over the power lines ordering controllers at selected houses to turn off for periods of typically 15–30 minutes; the shutdown call then rotates to another group of houses.

The effect is barely noticeable to the consumer (water stays fairly hot in the tank, for example), but the cumulative effect should be significant: by the mid-'90s, expanded use of such load management practices will enable Florida Power & Light to cut its peak demand by 340 megawatts, thus eliminating the need to build a new generating plant, according to spokesman Tom Veenstra.

In commercial buildings, there is another way to slash peak-hour electrical use without surrendering autonomy to a centralized load management system. For cooling, a growing number of Sun Belt buildings now run energy-hungry compressors through the night, when rates are low, to fill tanks with cold water; during the day, the cold water is piped through a heat exchanger to cool a stream of air.

In Dallas alone, over 14 million square feet of office space is cooled in this way, according to Loren McCannon, chairman of the International Thermal Storage Advisory Council (San Diego), a nonprofit organization promoting the technology. More than a dozen utility companies now subsidize purchases of cold-storage systems, he says; Southern California Edison, for example, pays $200 per kilowatt of load shift, up to a maximum of $100,000.

While many of the first cold-storage systems cooled air using water refrigerated to about 40° F, the trend is toward using ice water, to make the air even colder. That way, a smaller volume of chilled air is needed to produce the same effect. The net result: smaller ducts, less space required between stories, and lower structural costs.

mal energy. On a typical summer day, the average temperature during a 24-hour period might be about 75° F. A building that kept to this average temperature—storing the cool of the night for use during the hot hours when the sun is shining—would need minimal air conditioning. One way to do this is with very thick brick or stone walls, which have a large thermal mass; that's how the Indians of the American Southwest kept their dwellings comfortable in the searing desert sun.

But a similar effect can be produced without drastic structural modifications. The key is the installation of floors, ceilings, or walls in which is encapsulated a material that undergoes a phase change, such as melting, at a moderate temperature. As long as there is enough of this substance that it never completely melts or freezes, the building's interior will tend to stabilize at the phase-change temperature—the same way that a glass of ice water stays at around 32° until all the ice has melted. During the winter, a phase-change material stores the heat of the day by melting; at night, this heat is liberated as the material refreezes.

The most highly developed phase-change material for thermal storage is Glauber's salt (hydrated crystals of sodium sulfate), which costs little but has several drawbacks. Although it melts at 73°, the liquid tends to "supercool" below that point before freezing. Thus the release of energy occurs at lower temperature than would be most comfortable. Also, repeated thermal cycling sometimes breaks apart the hydrate, driving the water from the sodium sulfate and hence destroying the material's phase-change properties. The substance is also sensitive to humidity; it performs poorly if the air is too moist or too arid. Most of these problems can be overcome, but only with processes that add considerably to the material's cost.

Paraffins, a class of phase-change materials composed of long, straight hydrocarbon chains, may prove more practical. Under development at the University of Dayton Research Institute, these materials can be introduced into ordinary building materials such as plasterboard or cement. The waxy substances are available as unwanted byproducts of oil refining for under $1 a pound, according to Dayton's Ival O. Salyer, whose work is sponsored by the Department of Energy. Different blends can yield melting points at almost any temperature between 60 and 100° F. A potential drawback is that paraffin, unlike salt, is flammable. But "it burns like a candle, not like gasoline," Salyer points out. "You're not going to turn a house into the *Hindenburg*." In any case, a fire-retarding substance can be dissolved in the hydrocarbon as a precaution.

Applications for the phase-change material go beyond buildings, says Salyer. Fabric could be infused with the stuff to make lightweight clothes with the insulating value of much bulkier garments, for example, and a phase-change drinking mug would keep coffee hot longer than ordinary ceramic or styrofoam. Asphalt or concrete containing the phase-change material could serve as a nonfreezing pavement for bridges.

The Solar Energy Research Institute (Golden, Col.), meanwhile, is developing compounds that change phase while remaining solid. Materials exhibiting such solid–solid transformations could be incorporated into building structures without requiring special adaptations to seal in a liquid, notes SERI researcher David K. Benson. Typically, in one phase the material's molecules are locked into place in a crystal lattice; at the transformation temperature (which is usually far below the material's melting point), chemical bonds break to allow the molecules to spin and vibrate in place. Benson has experimented with trimethylolethane and neopentyl glycol, which can be blended to give a wide range of phase-change temperatures.

SERI researchers have also found a way to exploit the "nuisance" of supercooling in salt hydrates, with a technique for initiating freezing with an external signal. A tank of such material could be linked to a thermostat to provide better control over temperature—for example, postponing the release of one day's heat until it is needed the following afternoon, rather than squandering it at night when most people accept colder indoor air. And if salt hydrates were used in large quantities (say, a 500-gallon tank), SERI's technique could be employed for seasonal storage, saving up summertime heat for use during the winter. "You could turn on a switch at Christmas and bathe in the warmth of July," says Benson.

Energy efficiency does not necessarily depend on advanced technology. Indeed, some of the most impressive results have come from "superinsulated" houses, made from existing materials, that keep

warm through an icy winter while burning minimal fuel. Such homes can be built at a cost only 2–5% higher than conventional ones but incur one-fifth the heating cost, according to Robert Corbett, senior building technology specialist at the Department of Energy's National Center for Appropriate Technology (NCAT) in Butte, Mont. NCAT built five superinsulated model homes in eastern Montana several years ago, and is now monitoring their energy consumption. Corbett says that a 2000-square-foot dwelling in Great Falls stays warm all winter with $300 worth of electric heat.

Superinsulated homes typically have twice as much wall and roof insulation as conventional homes. The main idea is to eliminate "thermal short circuits"—uninsulated gaps through which heat escapes. Commonly, for example, insulation is omitted at the wall studs; wood is a relatively good heat conductor, and studs occupy up to 15% of wall space.

Innovative daylighting at Toronto's Victoria Park: Mirrors track the sun and focus its light into an array of acrylic "light pipes" that illuminate top-floor offices. The ceiling-hung tubes look like fluorescent fixtures—except the color is more natural.

One way to eliminate thermal short circuits is to add a second wall outside the first, filling the gap with insulation. Alternatively, a rigid slab of Styrofoam insulation can be placed between the wall studs and the exterior siding. But insulation only stops heat from escaping via conduction; meanwhile, as much as 60% of the total heat loss in a conventional home comes from air leakage. A fundamental principle of superinsulation, therefore, is to wrap the house in a continuous polyethylene membrane between the inner wall and the insulation. In addition to stopping air leaks, the plastic barrier prevents indoor humidity from permeating the walls, dampening and thus degrading the insulation. The extra-thick insulation and airtight construction have another benefit as well: they block out noise.

To prevent the airtight building from becoming stuffy or unhealthy requires forced ventilation. Ordinary homes are ventilated through accidental cracks and holes, which superinsulation eliminates. Thus superinsulated houses control air exchange to maintain a fresh indoor atmosphere while minimizing heat loss. The key piece of equipment is a heat exchanger, in which one stream of air transfers its warmth to another without mixing. A fan sucks indoor air outside via the heat exchanger; on its way out, this stale air raises the temperature of the cold, fresh air that's simultaneously entering from outside. Thus the house "breathes" without wasting energy. What's more, such forced ventilation allows greater control over other factors that affect comfort. To raise the humidity, for example, you could simply slow down the air-exchanger fans, allowing the naturally generated indoor moisture to build up.

Before the effectiveness of superinsulation was demonstrated—first in Sweden, then in Canada, now in the U.S.—it was widely thought that slashing energy use would require a building to sponge up solar radiation with a vengeance. That turns out not to be the case, however. A house generates considerable "internal gain" from light bulbs, appliance motors, body warmth, and so on; in a sealed, thickly insulated structure, this heat builds up significantly.

Thus, superinsulated houses rely only marginally on "passive solar" techniques. They don't typically have elaborate rooftop collectors or large sunspaces. Many even have windows on the north as well as south sides, for example, in violation of a cardinal tenet of solar design. According to Corbett, NCAT designers originally expected that the five model homes in Montana would draw a third of their heat from the sun. The surprising result: the sun carries a mere 12% of the burden, with 55% coming from internal gains; the balance is supplied by auxiliary electric heating.

Right now the NCAT houses are among only a handful of homes that can be called superinsulated. But the Canadian government is working with that country's home-building industry in an ambitious effort to make such efficiency the norm. With its R-2000 program, Canada's Department of Energy, Mines and Resources is calling for the majority of new Canadian houses built by the turn of the century to conform to an extremely frugal energy standard. The R-2000 standard is "performance-based rather than prescriptive," explains Henry Tenden, manager of program delivery; that is, builders can use any method they choose, as long as the resulting home can be operated for under the stipulated number of kilowatt-hours per year. The specified energy budget is calculated from a formula that accounts for the house's size and local climate; a 2000-square-foot house in Toronto, for example, must use less than about 17,000 kilowatt-hours.

Since the program's inception in 1982, says Tenden, about 1200 Canadian homes have been built in strict accordance with the R-2000 standard. And the program is starting to pick up steam; half the R-2000 houses built to date went up over the past year.

The Canadian government's commitment to energy-efficient housing contrasts with funding cutbacks in the United States: the Department of Energy's fiscal 1987 budget includes under $9 million for research on building-shell items such as windows, walls, and roofs, down from $12 million last year. And, says Arthur Rosenfeld, who heads the building technology program at Lawrence Berkeley Laboratory, "the private sector doesn't do the job." Manufacturers of windows, insulation materials, light bulbs, and so forth "make incremental improvements but not quantum leaps forward," he says. Major glass companies such as PPG, for example, did not start producing low-e glass until it was demonstrated by start-up Southwall Technologies, originally a DOE contractor. Moreover, says Rosenfeld, industry organizations such as the Electric Power Research Institute and the National Association of Home Builders tend to reduce their own R&D outlays if they perceive federal apathy.

Rosenfeld calls current government policies short-sighted. Aggressive adoption of efficiency technologies in new and existing structures, he says, would cancel the need for about 150 electric power plants, and permit buildings to stay lit and comfortable for $50 billion a year less than is now spent. He argues that even though energy is cheaper and more plentiful today than in the '70s, efficiency should remain a priority. After all, buildings last a long time: "The structures going up now," he asserts, "will turn middle-aged in an oil-scarce economy." □

Herb Brody is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 65.*

OPTICAL COMPUTERS

In theory, they could run circles around electronic systems, but working models are a long way off

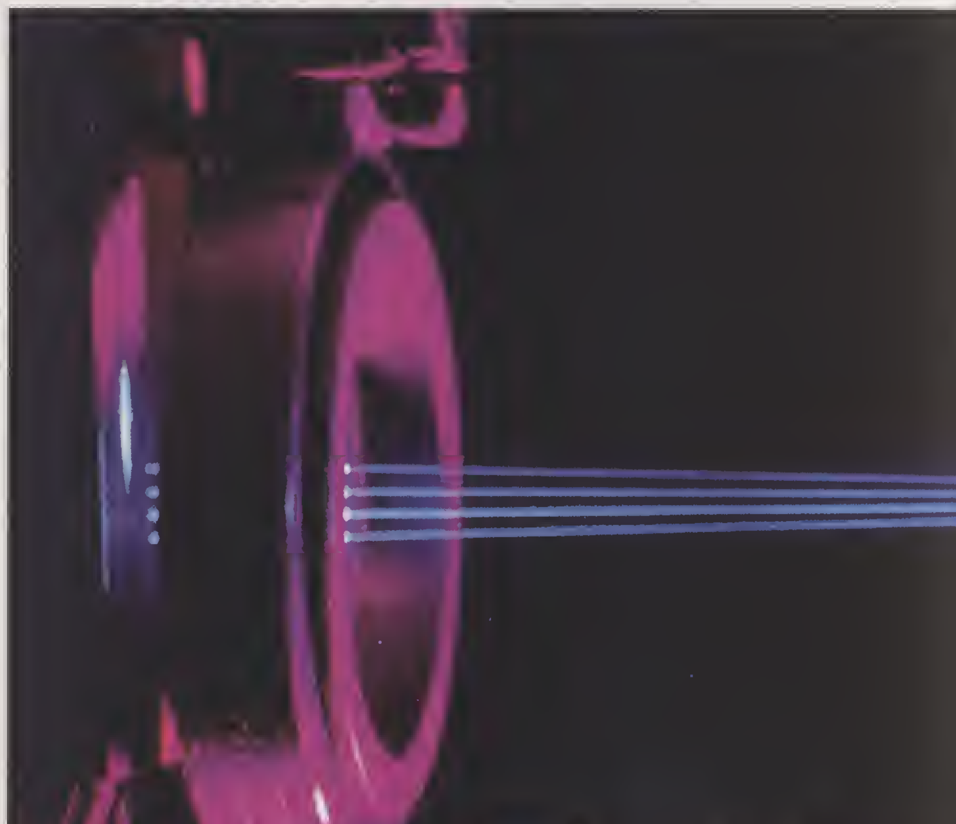
by Jeff Hecht

The potential is enormous. Computers performing a million billion operations each second, a thousand times faster than today's supercomputers. Machines that mimic functions of the human brain. All-optical communications networks that relay signals at high speeds around the world, without the electronic switches needed in today's fiber optic systems.

What unites these visions is a vaguely defined concept called optical computing. Computing with light is not completely new; special-purpose optical processors have long been used to recover images generated by certain kinds of airborne radar, and other systems rely on the interaction of light and sound in crystals to monitor the radio spectrum. Now, researchers are starting to move beyond analog devices into the realm of digital computers. Most demonstrated devices are far from being practical and economical. But in theory, optical systems can zip data between circuit boards, or between chips on each board, faster than electronics can. And some tasks that challenge even the browniest electronic computer, such as quickly comparing patterns, are relatively easy with optics. Those capabilities could have many practical applications, from robot vision to automation of operations in NASA's planned space station.

An optical computer would have three main strengths: speed, parallelism, and density of interconnection.

- **Speed.** The fastest electronic transistors take several picoseconds (trillionths of a second) to switch between on and off states. Light beams, however, have been switched far more rapidly; the shortest optical pulse so far is a 0.008-picosecond flash generated at AT&T Bell Laboratories. Moreover, light travels faster than electricity, and there is no optical equivalent of the capacitance that slows down signals in conductors. And while electronic devices speed up as they shrink, that's not true of the wires that connect them. It takes at least 50 nanoseconds (billionths of a second) for an electronic signal to move between two circuit boards on a computer, while light, which travels at 30 centimeters per nanosecond, could make the same trip much faster.



Light travels faster than electronic signals, it can be switched more rapidly, and information can be processed in parallel on multiple neighboring beams. These attributes should make optical computers a thousand times more powerful than conventional machines, says Bell Labs research leader Alan Huang (right). Above: A prototype device developed by entrepreneur Peter Guilfoyle uses lasers to perform many simultaneous multiplications.

- **Parallelism.** Ten thousand independent light beams can pass through an ordinary lens. Thus an optical device can accept multiple inputs at the same time. In most electronic computers, by contrast, the data for all computations pass "single file" through a main processor.

CHUCK O'PEAR; FROM "HIGH TECHNOLOGY WINDOW TO THE FUTURE"

• **Interconnection.** Light rays, unlike electrical currents, do not affect each other. Optics could therefore allow denser arrays of interconnections to and within a chip than are possible with electronic conductors.

A group led by Alan Huang at Bell Labs in Holmdel, N.J., wants to use all these optical properties to build supercomputers a thousand times more powerful than today's models. But most present work aims to graft lightwaves onto conventional electronic machines rather than to construct radically new computers.

"The rush to pack more and more computing capability into today's electronic systems will soon be radically slowed unless a major change is made in intracomputer communications," warns John A. Neff of the Defense Advanced Research Projects Agency (DARPA) in Arlington, Va. The problem is that the number of connections needed, both within an integrated circuit and to other chips, increases faster than the number of elements on a chip. Neff believes that designers of very-large-scale integrated circuits containing several hundred thousand devices would face severe constraints if limited to the 200–300 input/output pins promised by new electrical technology.

In one DARPA-sponsored effort to overcome the problem, researchers at Columbia University's electrical engineering department strip optical fibers down to their cores and insert them into tiny laser-drilled holes on the face of the chip. Deep within the chip are photodiodes that convert the incoming optical signals into electronic signals that travel to other portions of the circuit. By making connections to the chip surface—instead of to the perimeter, as in conventional ICs—the Columbia team hopes to overcome a perennial bottleneck: as a chip's surface area is expanded to hold more devices, the increase in its perimeter is disproportionately small.

Besides allowing more input and output of data, optics could streamline a chip's internal operation. For example, a small semiconductor laser could direct precisely timed clock pulses through the air to photodetectors on a chip. (ICs require such clock signals to make sure that all elements operate synchronously.) Because the light beam arrives at all points on the chip simultaneously, this scheme avoids the delays that ensue from conventional electronic propagation on the IC—in which a current must travel the entire

length of the chip, reaching some elements before others. In one approach under development by Larry A. Bergman of Jet Propulsion Laboratory (Pasadena, Cal.), a special hologram splinters the laser output into four or five beams and focuses each onto one of the photosensors distributed evenly around the electrical conductor carrying the clock signal. The signal need then travel only a short distance in electronic form. Similar work is being done by Jeffrey Fried of GTE Laboratories (Waltham, Mass.) in one of the few optical computing projects not funded by DARPA.

The new technology could make possible a more fundamental advance than merely speeding up conventional machines. "Optical computing should lead to wholly new machines that 'think' rather like humans instead of 'number crunch' like electronic digital computers," says Hyatt M. Gibbs, professor of optical sciences at the University of Arizona (Tucson) and director of the industry-sponsored Optical Circuitry Cooperative.

A single neuron in the brain can fire only a few times a second—far slower than electronic switching. Its association with thousands of other neurons, however, permits extremely rapid performance of tasks such as pattern recognition. With their potential for massive interconnection, optical computers might have similar capabilities.

An optical computer's blazing speed may compensate for the somewhat reduced accuracy that accompanies associative types of processing. But Gibbs points out that for processes such as pattern recognition, "it is sometimes better to have a 95% accurate answer quickly while it is still useful than a 99.999% answer after it's too late."

One of the first areas of computing to turn to optics has been data storage; optical discs can hold far more information than their magnetic counterparts. Today's optical memories are read one bit at a time by a laser beam focused to a small spot. Vastly more powerful would be parallel readout, with a broad-area beam bathing the entire disc at once. The reflected image would be examined for a particular pattern of marks signifying, say, a key word, much as a person scanning a newspaper page can rapidly zero in on a story of interest without having to read every word on the page. The laser would retrieve entire data records containing that identification pattern at once, speeding data access perhaps a thousandfold. Demitri Psaltis of the California Institute of Technology's electrical engineering department has already demonstrated such image retrieval from photographic film. "If optical memories become commonplace," he says, "it will be inevitable that parallel access of these memories will be attempted in order to get to the stored information faster."

SPIDER MARTIN/BLACK STAR

At Hughes Research Laboratories (Malibu, Cal.), Bernard H. Soffer and colleagues have reproduced a holographically stored image by illuminating the hologram with only part of the image; Such associative recall via a partial image is also being attempted in liquid crystal displays by researchers at Jet Propulsion Laboratory, the University of Southern California, and San Diego State.

In their simplest form, associative optical memories can search for only one chunk of information at a time. But scientists Ravinda A. Athale of BDM (McLean, Va.) and Harold H. Szu of the Naval Research Laboratory (Washington, D.C.) have proposed a memory that looks for many objects at once or for different characteristics of a single object. NASA is interested in associative memories because its space-station plans call for robots to perform tasks with little supervision and few constraints—conditions that require decision-making capability. To make the proper decisions, such autonomous robots will have to recognize objects regardless of their orientation or context.

Farther off are optical computers that manipulate data in digital form, much like

Caltech's Demitri Psaltis is working on an "associative" optical memory that would speed readout by identifying patterns in the stored information, much as a person can zero in on a newspaper story of interest without having to read every word on the page.

The U. of Alabama's H. John Caulfield stresses that optical computing is in its infancy: "Most of this stuff is still chalkware."

today's electronic machines. A major goal is to solve the matrices—arrays of numbers representing multiple variables—that are used to set up many scientific and engineering problems. Matrices are hard to handle in conventional computers because many inputs are needed to calculate each matrix element; but an optical computer, with its high degree of interconnection, is made to order.

Manipulating matrices permits the simulation of natural processes or man-made events involving large amounts of complexly interrelated data. For example, the temperature, pressure, and water-vapor content of one part of a swirling cloud can be estimated from earlier values of those quantities throughout the cloud. Other matrix operations can help an automated weapon system evaluate readings from a vast array of sensors—each generating an output with a known mathematical relation to some physical phenomenon—thus letting the system distinguish the trees from the tanks.

Many optical approaches to matrix manipulation have been studied. Among the most intriguing is the "systolic array" advocated by H. John Caulfield, director of the University of Alabama's Center for Applied Optics (Huntsville). Originally developed for VLSI electronics, systolic arrays are designed so that all the inputs needed to calculate a particular matrix element arrive at one processor at the same time. Meanwhile, some of those same inputs may simultaneously be routed to other, parallel processors, along with additional inputs, to calculate other matrix elements.

JAMES CACCAVO

At Hughes, Soffer is working on a 64×64–element matrix multiplier that relies on spatial light modulators—crystals whose transparency or reflectivity can be adjusted independently at different points on their surfaces in response to an electronic input signal. Because it's difficult to make a modulator that can address both rows and columns (one problem is attaching the electrodes so they don't block too much light), Soffer's group achieves essentially the same effect by overlaying two modulators, the elements of one running vertically, the other horizontally. Soffer's processor works with analog inputs. It could attain higher accuracy by going digital, but at a cost: speed drops or size increases in proportion to the number of bits in the digitized signal.

The Aerospace Industries Association of America (AIA), based in Washington, D.C., is trying to establish an industrial research consortium to push optical computers for matrix manipulation. For aerospace use, the group wants an optical computer "to perform computations about a thousand times faster than current mainframes, and still be compact and rugged," says AIA program coordinator Richard McDonald. Within five years, AIA seeks an optical system able to multiply a pair of 100×100 matrices in a millisecond. The consortium will be formed as a separate corporation, and McDonald says that sometime this year it should begin requesting proposals for optical computing research.

Because of optics' suitability for matrix manipulation, along with the high speed and massive parallelism that underly such applications, the technology has aroused strong interest on the part of the Star Wars program. Strategic Defense Initiative planners also cite the relative immunity of optics to electromagnetic pulse and radiation produced by nuclear explosions, which can disrupt the operation of electronic circuits.

A full-blown defense system would require formidable sensing and computing power. In a matter of seconds—or at most minutes—a defense system must be able to find and track thousands of warheads thousands of miles away, each perhaps a yard across. It must be able to tell warheads from decoys and from objects in the background. To increase the system's

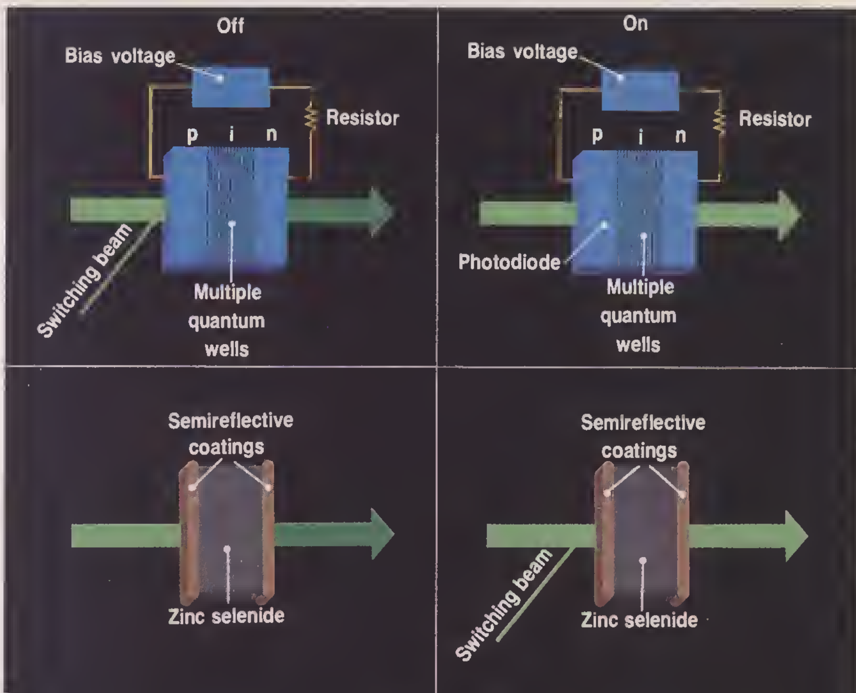
chance of survival, SDI planners hope to distribute computing power to many points rather than centralize it. Each computer will receive data from many sensors, looking at the same region of space from different viewpoints and in different parts of the electromagnetic spectrum.

Much of the data might take the form of matrices—for example, one value for each picture element in a high-resolution image. The computer's job would be to compare the data with the characteristic "signature" of a nuclear warhead. If the data of several sensors correlated to what was expected from a warhead, the defense system would open fire. As evidence of its interest, the SDI Organization chose to fund optical computing work in one of its first university–industry research consortia. The goals are ambitious. Alabama researcher Caulfield, who heads the consortium, says he was told to "look for breakthroughs—orders-of-magnitude improvements over what can be done electronically." Tellingly, optical computing is being funded out of SDI's basic research office; there remain large conceptual gaps between optical computing theory and the hardware needed to implement it. "Most of this stuff is still chalkware," says Caulfield.

Regardless of its application, a digital optical computer will need its own version of a transistor—in other words, a device that allows one light beam to control another. Such optical switches must be not only fast but efficient, to avoid shedding too much waste heat.

Great strides are being made in optical devices that can be switched between high and low levels of light transmission. There are many variations, all switched between two states by nonlinear effects that let a small change in input produce a much larger change in optical properties.

One leading approach, pioneered at Heriot-Watt University in Edinburgh, Scotland, uses a thin slab of a semiconductor such as indium antimonide or zinc selenide, sandwiched between a precisely spaced pair of semireflective mirrors. One laser beam illuminates the device at a level slightly lower than that needed to switch from low to high transparency, much as a bias voltage readies a transistor for operation. A second, weaker, optical beam pushes the device above the threshold for high transmission, turning it on. The device is bistable—it remains in the "on" state even after the extra input is removed, because the pair of mirrors cause light to bounce back and forth within the device. This resonant cavity stores enough energy to keep transmission high. S. Desmond Smith's group at Heriot-Watt has used such devices to build a simple "finite state" computer, which circulates logic signals around a closed loop (see HIGH TECHNOLOGY, Dec. 1986, p. 65.).



A digital optical computer would need a device that permits a weak signal beam to control a stronger beam, similar to the operation of transistors in an electronic computer; groups of such switches could serve as logic gates (e.g., AND, OR). In the electro-optic switch developed at Bell Labs (top), the addition of a switching beam produces an electric current in a photodiode, thereby reducing transparency to the main input beam. Heriot-Watt University's device (bottom), which requires no electrical connection, works the opposite way: the switching beam effectively "bleaches" a mirrored semiconductor slab so that more of the input gets through.

IMAGE BUILDERS

A different approach, developed by David A. B. Miller at Bell Labs, uses a more complex semiconductor to avoid the need for precisely spaced mirrors. Miller's "self electro-optic effect device" (SEED) has many thin alternating layers of two slightly different compositions. Such a structure forms "quantum wells," which exploit the wavelike nature of electrons by confining them to an extremely narrow region. The material's ability to transmit light varies with the applied electric field; Miller dopes the semiconductor to make it a photodiode, so that such a field changes in response to illumination. Thus a beam trained at the SEED controls the portion of a second beam that the device will transmit. Last spring, Miller's group reported making a 2 × 2 array of SEED switches on a single chip—an important step because they had previously used discrete components. Miller aims to extend the process to making larger arrays.

SEED devices are far from the ultimate in optical switching; with a switching time of about a nanosecond, they are little faster than the best electronic transistors. But higher speeds may be possible with other quantum-well devices. In the "optical logic etalon," developed by Bell Labs researcher Jack Jewell, an input beam at one wavelength changes the device's transparency to a probe beam of a different wavelength; switching times of 60 picoseconds have been achieved. And Lawrence West, also of Bell Labs, is working on a new quantum-well effect that he believes will allow switching times of 0.1 to 0.2 picosecond.

Bistable optical elements, like transistors, can serve as building blocks for logic circuits. Researchers at Heriot-Watt and elsewhere have made circuits that perform most of the common logic functions: AND, OR, NAND, exclusive-OR, and NOR. Serious obstacles remain, however. Present devices take many times the switching speed to recover so they can switch again. Also, to be practical, the output of one logic gate must be able to drive the next gate; many bistable optical devices are not "cascadable" in this way, because the output is

JAMES LEGOY

Peter Guilfoyle attempted to commercialize an optical matrix multiplier as an add-on to conventional computers. He failed, but he hasn't given up; Guilfoyle founded a second company, OptiComp, to continue research on the idea.

either too weak or of the wrong wavelength. Moreover, gains in speed are usually matched by rising power consumption: the faster the device, the more energy needed to switch it, and the more heat it has to dissipate. "Some optical computer schemes in the literature would require weapons lasers in order to operate at their projected speeds," says Caulfield.

While a general-purpose optical computer is still a long way off, some of the same technologies may find more immediate application. Fiber optic communications systems, for example, could benefit from all-optical switches. Present fiber optic links carry lightwave signals long distances, but must convert them back to electronic form for amplification or routing to different parts of the telecommunications network. The signals are then changed back to light for retransmission. "Conversion between optics and electronics is the slowest, most expensive part of switching," says Huang. An all-optical system would avoid the inefficiencies and errors that creep in during these multiple conversions.

Researchers seeking optical switching are looking not only at bistable optics but also at other technologies. In one class of devices, known as integrated optics, light is confined to the surface of a lithium niobate crystal. Application of an electric field to such a "planar waveguide" affects how light is transmitted, changing its intensity either directly (by letting some leak out of the waveguide) or indirectly (by altering polarization so some light can be removed from the beam with a polarizing filter). Such devices can thus function as electrically triggered light switches.

Integrated optics have been under development since the late '70s, with some encouraging successes. Researchers at the TRW Electro-Optics Research Center (Redondo Beach, Cal.) have demonstrated an integrated optic device that functions as an exclusive-OR logic gate. And a team from L. M. Ericsson and Rifa AB in Sweden and the Heinrich Hertz Institute in West Berlin has made an array of planar waveguides that can route the beams from eight input fibers into any of eight outputs. Though an impressive accomplishment, the array suffers from high loss; only 5% of the input signal passes through to the output. Another drawback is that tens of volts must be applied to each of the 64 elements of the switch. And the switching capacity demonstrated is far from that needed to handle thousands of telephone lines.

Large firms are expressing interest in joining research consortia such as Arizona's Optical Circuitry Cooperative. The list of companies contributing $50,000 a year to that program is a who's who of electronics and aerospace: AMP, Boeing, Celanese, Dow Chemical, IBM, Lockheed, Motorola, Sperry, 3M, and TRW, among others. Nevertheless, research is largely confined to such rarefied environments, and has a long way to go before anyone can consider building an all-optical version of a VAX computer.

But the first—and so far the only—serious attempt to commercialize optical computing was by a start-up called Guiltech Research (Sunnyvale, Cal.). Guiltech, formed in 1981 by Peter Guilfoyle, an optical engineer from Itek, aimed to build an optical matrix multiplier that would serve as an adjunct to mainframe electronic computers. The mainframe would handle other problems, then pass matrix problems to the optical system for fast processing. As a result of a management shake-up in 1985, Guilfoyle departed and the company abandoned the optical approach in favor of a more conventional electronic solution. Guilfoyle has started another company—OptiComp, in Zephyr Cove, Nev.—to continue research on the technology with military funding, but no products are planned.

Indeed, it will probably be a long time before anyone attempts to build an optical version of a VAX computer. "Optics does not have a chance of displacing electronics in computers unless it promises improvements in computational power in excess of two orders of magnitude," says William T. Rhodes, electrical engineering professor at Georgia Tech and one of the top authorities in the field. "I doubt seriously that we have the basic concepts in hand right now to do that," he adds.

Still, optical computing researchers stress that the field is embryonic. Says Alabama's Caulfield, "We are roughly where electronic computers were in the mid-1940s." □

Jeff Hecht is a Newton, Mass., writer specializing in optical technology. His latest book is Understanding Fiber Optics *(Indianapolis: Howard W. Sams, 1987).*

For further information see **RESOURCES**, *p. 65.*

CONSUMER TECHNOLOGY

TAKING THE *FFFFF* OUT OF FM RADIO

FM stereo radio is currently the only high-fidelity audio medium still afflicted by background noise. But audiophiles can take heart: a new noise-suppressing technique is arriving that will let broadcasters transmit compact disc recordings and live concerts without compromising sound quality. In addition, the new scheme—called FMX, for extended-range FM—triples the station's area of coverage.

FM's present shortcoming stems from a choice made a quarter century ago, when two radio manufacturers—Crosby and Zenith—proposed different methods of stereo broadcasting. Both worked by piggybacking two audio channels onto each FM signal. Crosby's method would have provided superior stereo reception with wide channel separation and low noise. However, the stereo broadcast would not have been fully compatible with mono-only receivers still in wide use at the time. The Federal Communications Commission, concerned that such an incompatibility might retard the commercial growth of the then-small FM broadcasting industry, instead chose Zenith's approach, which promised full compatibility, but with a higher level of noise that degraded the signal.

FM broadcasters have evolved two techniques—both seriously flawed—to overcome the medium's inherent noise. Stations commonly impose a minimum signal level, so that any musical passages quieter than a certain threshold are amplified to be heard above the noise. While this is acceptable with pop music—which usually is recorded at a constantly high volume anyway—such sound compression robs some classical music and jazz of its subtle dynamics.

The other noise-suppression scheme evolved in the days of the ribbon microphone and 78-rpm record. Both of these obsolete audio sources captured high-frequency overtones rather weakly. Thus stations boost, or "pre-emphasize," the high frequencies in every signal by 15 decibels prior to broadcast—the equivalent of turning the treble all the way up. A complementary circuit in every FM receiver brings the boosted highs back down to the correct level and dulls any hiss.

by Peter W. Mitchell

Today's recordings, however, have much stronger high-frequency content. A constant degree of pre-emphasis would produce intense enough signals to interfere with adjacent stations (the louder an FM broadcast, the larger a chunk of the spectrum it occupies). Thus to prevent the signal from splattering into other channels, stations boost the highs less when the music is loud. But such weakening dulls the received sound, squashing the brilliance of percussive instruments such as bells and cymbals.

The compression and dulling of FM sound is becoming more obvious as listeners grow accustomed to the vivid, wide-range sound of CDs. FM radio has needed a technological advance, but progress has been hobbled by the need to remain compatible with the 100 million radios already in use. In principle, noise in FM could be suppressed with the same devices common in stereo tape recorders. But those circuits (such as Dolby or DBX) alter the sound when it is recorded or transmitted. Listeners lacking a complementary decoder would hear only the altered sound.

FMX cancels the noise penalty that has accompanied stereo FM since its inception.

FMX, developed by the CBS Technology Center (Stamford, Conn.) and the National Association of Broadcasters (NAB), retains full compatibility with existing radios. The FMX-encoded portion of the signal is ignored by conventional receivers, but for listeners equipped to take advantage of the system, noise is dramatically reduced.

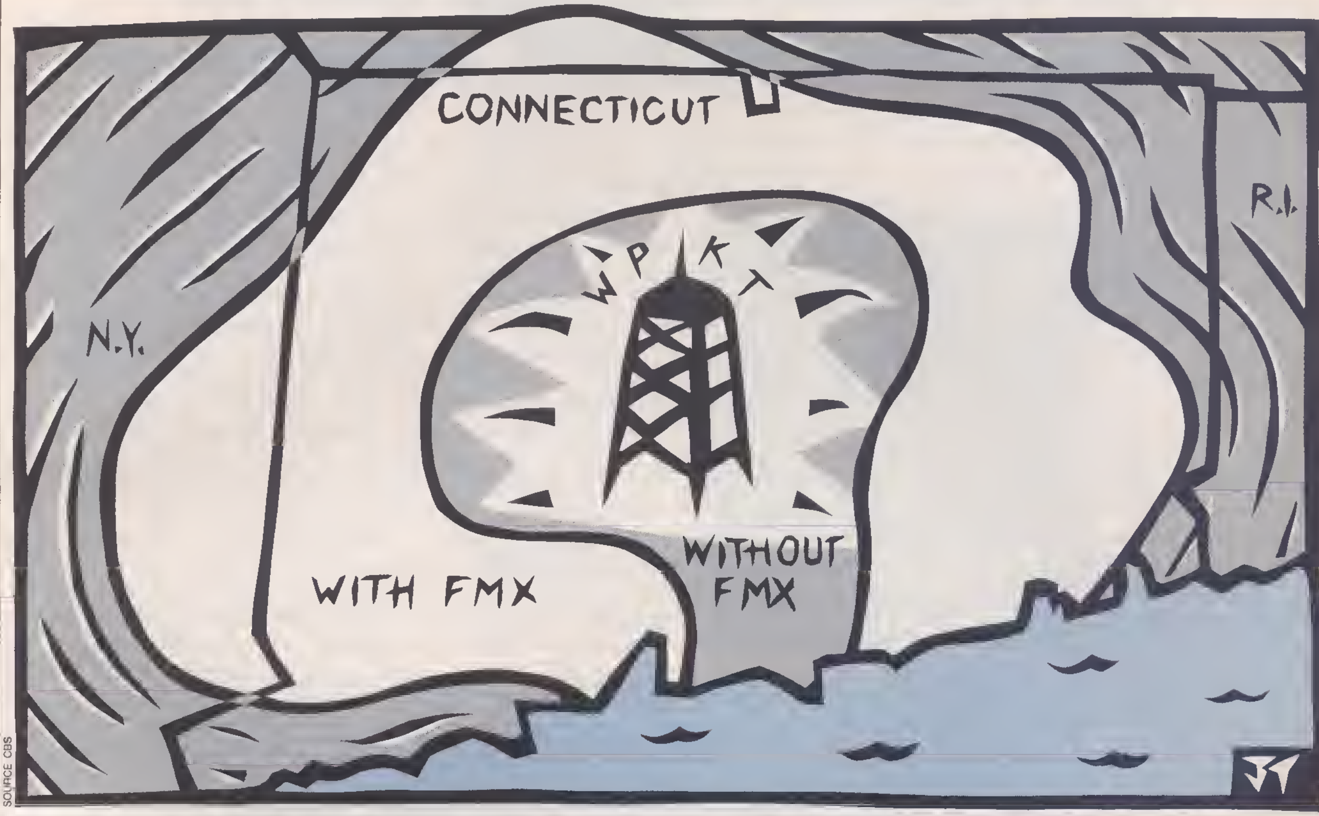
All stereo FM broadcasts consist of two parts. The left and right channels are added together and transmitted as a conventional mono FM signal (L plus R). At the same time, the stereo difference signal (L minus R) is transmitted over a "subcarrier" frequency 38 kilohertz (kHz) away from the center of the FM channel. The receiver combines the L + R and L − R signals to recover the left and right audio channels.

The mono portion of the composite signal is received with very little noise. The L − R stereo portion, however, is accompanied by a noise level that is 20 decibels (dB) higher. One reason is that it is broadcast in a higher frequency range, where naturally occurring electrical noise, including radio hiss, is stronger. Tuner manufacturers have tried many tricks to suppress the noise in the stereo subcarrier, but alteration of the L − R signal invariably impairs the stereo image.

To retain compatibility with existing receivers, FMX alters neither the mono nor the stereo portion of the broadcast. Instead, it uses the 38-kHz subcarrier for two L − R signals. One is unaltered, just as in today's FM broadcasting. In the other L − R signal, however, quiet passages are boosted by 20 dB, keeping them far above the noise. In this sense, the technique resembles the sound compression that FM stations already practice to the detriment of musical subtlety. But FMX-equipped tuners will extract the modified L − R signal and push the quiet passages back down to their original low level—thus retaining the original dynamics of the sound—and simultaneously suppress the residual noise by 20 dB, canceling the noise penalty that has accompanied stereo FM since its inception in 1961.

In principle, the additional subcarrier has no effect on reception by any radio lacking an FMX decoder. Such transparency is possible because virtually all existing radios synchronize their detection circuits with the incoming signal; the detectors can respond to the L − R subcarrier only when that waveform is reaching its peak. The FMX subcarrier, however, is shifted a quarter cycle out of phase; it is just crossing through zero—and is thus imperceptible—when the detectors are opening up to sense the main subcarrier's peak.

Several major FM stations around the country commenced on-air testing of FMX last summer, with deliveries of the first production encoders during the fall. As many as 100 stations could begin FMX broadcasting by spring. Conversion to the reduced-noise system requires that a ra-



By allowing clear stereo reception farther from the transmitter than possible before, FMX triples the coverage area of WPKT in Meriden, Conn., one of the first stations to use the technique.

dio station replace its existing stereo generator with a new one containing the FMX-encoding circuitry, at a total cost of about $5000. FMX generators are being manufactured by Circuit Research Laboratories (Tempe, Ariz.) and Orban Associates (San Francisco).

So far, only one company—NAD (Norwood, Mass.)—makes FMX-equipped tuners and receivers, and much of NAD's initial production is being absorbed by radio stations to monitor their own broadcasts. A number of other audio manufacturers—including Apt, Adcom, Tandberg, Pioneer, and Magnum—also plan to make FMX-equipped tuners, but they are awaiting the availability of a complete FMX decoder on a single integrated circuit.

The first such chip is being developed at Sprague Electric (Worcester, Mass.). Sprague's IC will contain the conventional L − R decoder as well as the added circuitry for FMX. Because this chip will replace the normal stereo IC, an FMX tuner will have about the same number of parts as existing tuners and will cost essentially the same to produce, according to Sprague applications engineer Oliver Richards. The FMX chip will be available to manufacturers early in 1987. If FMX proves popular, other companies are expected to begin making equivalent ICs. Sanyo, for example, is already tooling up.

FMX provides the most noticeable improvement in automobiles, where stereo reception is notoriously poor, mainly because the antennas are so small. In a demonstration by CBS and NAD early last year, FMX completely silenced "picket-fencing"—the *fft-fft* noise produced when a car moves through zones of rapidly varying signal strength.

But the new system won't solve all of FM radio's problems. It will not help, for example, where reception is hampered by multipath interference. In this situation, common in cities, noise is generated by the interference of radio waves coming directly from the transmitter with waves that have bounced off tall buildings. In fact, FMX might make matters worse under such conditions. In principle, severe multipath effects could shift the phase of the subcarrier waves enough so that the FMX signal would be detected by a non-FMX receiver, which lacks the decoding circuitry. As a result, volume or stereo separation might be altered. Last summer, tests in Phoenix by Circuit Research Labs gave mixed results. FMX did indeed worsen reception on non-FMX radios—but only at locations where multipath effects already rendered the station almost unlistenable.

More definitive tests are needed, under controlled conditions. CBS probably would have conducted such tests last fall, but the company's management upheaval put FMX activity on hold (with hundreds of people being laid off, a decision about FMX received low priority). If CBS backs out, though, codeveloper NAB will take over promotion and licensing. Then it will be up to the station owners to decide whether the benefits of FMX outweigh the risk of impaired reception for some listeners—just as they earlier had to decide whether to convert to stereo despite poorer reception by some mono-only radios. □

Peter W. Mitchell is a recording and product design engineer who writes frequently about audio, video, and computers.

THE ADVANCED TACTICAL FIGHTER: SMARTER, STRONGER, NIMBLER

Under sponsorship of the U.S. Air Force, the "fighter of the future" is being built today. Engineering teams are developing the technologies that will contribute to two prototype Advanced Tactical Fighters (ATFs) designed to meet strategic needs such as short takeoffs and landings, cruising at supersonic speeds, and high maneuverability for air-to-air battles, along with stealth characteristics and the capacity for low-altitude flight at high speeds in order to minimize detection by enemy radar. "The ATF will be the Air Force's air superiority fighter for the year 2000 and beyond," says Lt. Gen. William E. Thurman, commander of the Aeronautical Systems Division (ASD) at Wright-Patterson Air Force Base in Ohio, which manages the ATF program.

To reach its target of starting a production run of 750 aircraft at $35 million apiece by 1991, ASD has subdivided the program into various independent Air Force ventures that focus on developing new technologies—some of which are already being tested on modified versions of current aircraft—and extending old ones. New composite materials will make the fighter stronger, lighter, and harder to detect. Very-high-speed integrated circuits (VHSICs) combined with expert systems will allow integration of previously unrelated systems on the aircraft. But the major difference between the ATF and today's fighters, says ATF program director Col. Albert Piccirillo, will come in the avionics. They will provide so much information that pilots will have to rely on artificial intelligence to help them make decisions.

To avoid the escalating costs endemic to major defense projects, ASD has adopted a recommendation of the Packard Commission on Defense Management: it requires working prototypes of major ATF components before awarding contracts for full production. While realistic cost estimation is the objective, there is an added dividend. As a result of the prototyping, asserts Piccirillo, "we will have ATF airframes and engines flying almost two years earlier than originally planned."

ASD is awarding contracts for the prototypes at a steady pace. In October 1985 and last April, Boeing Military Airplane Company (Wichita, Kans.) received separate awards worth $24 million and $6.8 million for developing the fighter's wings and cockpit automation technology. Last October, ASD announced that it was awarding two contracts for $691 million to build prototype ATF airframes—one to a team with Northrop (Hawthorne, Cal.) as the prime contractor in partnership with McDonnell Douglas (St. Louis), the other to a team headed by Lockheed (Burbank, Cal.) with General Dynamics (Fort Worth) and Boeing as its junior partners. The Air Force will choose between the two teams in 1990, and the fighter will move from prototype to full development the following year. The airframes must be compatible with each of two prototype engines—designated the YF119 and YF120, and built by Pratt & Whitney (East Hartford, Conn.) and General Electric (Schenectady, N.Y.) respectively—that are now undergoing ground demonstration tests.

The major difference between the ATF and today's fighters will come in the avionics.

The winning engine design will provide the foundation for an advanced Air Force program called the High-Performance Turbine Engine Technology (HPTET) initiative, which aims to produce novel engine designs that will appear in production ATFs by the year 2000. Such improvements as new combustors, digital electronic controls, and vector-thrusting nozzles will give the fighter higher thrust, as well as improved fuel efficiency and more reliability. The goal is to reduce ATF engine weights by 50%, while increasing thrust-to-weight ratios by 100% over those of the best current engines.

Because the combination of higher thrust rates with smaller engines will drive operating temperatures up to 3500°–4000° F, the HPTET initiative is also looking for new materials capable of withstanding such extreme heat. The most promising include ceramic composites, single-crystal alloys such as titanium aluminide, and carbon–carbon composites. And since lubricants used today reach their operational limit below 600° F, the program is seeking liquid lubricants that can perform at close to 1000° F and solid lubricants that work at 1500° F. Attempts are also being made to incorporate laminated parts. By allowing more water to pass through, a laminated porous material makes cooling more efficient and thus reduces engine wear.

To be effective at close range in dogfights, the ATF must be "super-maneuverable." To achieve this maneuverability, as well as short takeoff and landing capability, engineers at several Air Force and civilian facilities are developing the principle of vector thrusting. A vector-thrusting system works by diverting some of the jet exhaust away from the usual straight-back path. By aiming the thrust downward, vanes in the engine compartment can facilitate short takeoffs. Thrusting in other directions enables the pilot to move the aircraft sharply to one side without changing the direction in which it is pointing—an action sometimes referred to as a decoupled maneuver. Vector thrusting also allows a steeper angle of attack, an example of super-maneuverability that would give the ATF a great tactical advantage over other aircraft. Defense scientists hope to perfect the concept before the ATF airframe is built. The U.S. Navy is already testing a prototype vector-thrusting system in a Grumman F-14, while NASA is modifying a McDonnell Douglas F/A-18 with a simple vector-thrusting system it will test this year.

Another advanced new concept, the mission-adaptable wing (MAW), allows a single plane to assume the role of many. It can fly at supersonic speeds to reach a battle position, and then reconfigure to permit the tight turns essential for aerial combat. The MAW's outside edges are made of flexible fiberglass, and its flat upper surfaces can be cambered to form many configurations. The pilot alters the wing's shape by punching in a preprogrammed flap position.

A joint program run by the Dryden Flight Research Facility at NASA's Ames

by Salvatore Salamone

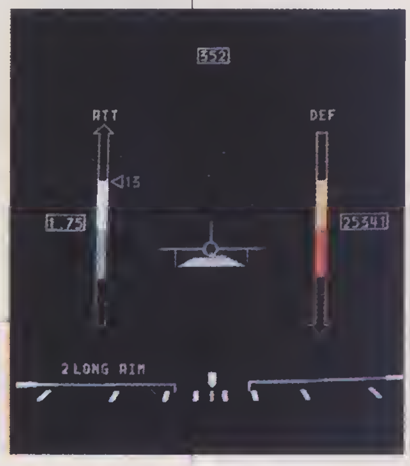
Research Center (Mountain View, Cal.) and the Air Force's Flight Dynamics Laboratory at Wright-Patterson AFB started the first of 30 tests of a MAW mounted on a U.S. Air Force/General Dynamics advanced fighter technology integration (AFTI) F-111 modified by Boeing Military Airplane. These tests, begun in 1985 and scheduled for completion in May, use preselected wing shapes that the pilot calls up manually. The long-range goal, however, is to develop an automatic flight-control system that can analyze the flight data in real time and continuously move the leading and trailing edge flaps to minimize drag and thus obtain maximum cruise speed. Other goals include a maneuver camber-control mode that will constantly change the position of both edge flaps to obtain the best lift-to-drag ratio, taking into account the plane's attitude and speed, and a maneuver enhancement mode to make the aircraft respond to pilot instructions more efficiently. The MAW is expected to improve an aircraft's range by about 25% and to provide a more stable platform for weapon release.

Even with the MAW, the ATF will need thinner wings, both to reduce drag and to reduce its visibility to enemy radars. To achieve this, the actuators that position the wings' control surfaces must be thinner and must operate at higher pressures than those currently in use. The Air Force's High-Pressure Low-Profile Actuator for Aircraft program is about to award a contract for such systems. HR Textron (Valencia, Cal.) has already developed a thin high-pressure actuator. Called Flat-Pack, it fits into the 2.62-inch maximum thickness specified for thin-winged aircraft, and can operate at 8000 psi pressure, considerably higher than the 3000 psi typical of current actuators.

High-pressure actuators won't provide the last word in control for the ATF. Project officials are now considering variable-pressure hydraulic systems. Designed to operate at normal pressure 90% of the time, these systems could be switched to high pressures when needed for takeoffs, landings, and high-speed maneuvers, and would last longer than those operating continuously at high pressure.

The ATF's highly sophisticated avionics will give pilots real-time access to data about the aircraft's performance, navigation systems, weapons systems, communications, and assessments of enemy threats. The problem will be how to put this vast quantity of information into a form that the pilot can use effectively in making decisions. One approach, developed by Boeing Military Airplane, is a pictorial head-up display for the Air Force Flight Dynamics Laboratory that shows the pilot the plane's altitude, bearing, and airspeed, as well as the distance to an approaching target and whether or not the target is within the "no-escape range" of the fighter's weapons.

New systems on the drawing board will use artificial intelligence to display enemy threats and enemy radar coverage, and then indicate the safest route to follow. A system under study at Boeing Military Airplane, for example, can use information from sensors to control the aircraft in such a way that it automatically flies a "nap of the earth" route, following the local terrain so closely that it evades radar detection. Another innovative idea, being developed at Georgia Institute of Technology, is to warn the pilot of a threat by producing sounds, through his headphones, that seem to originate from the direction of the threat.



Right: ATF head-up display tells the pilot when a target is in the "no-escape" range.

The mission-adaptable wing, envisioned for the ATF, was recently demonstrated on a modified F-111.

Pilots of the ATF must do more than respond to the fighter's cues. When putting the plane through its paces, pilots will have to withstand gravitational forces appreciably higher than present-day fighter pilots experience—forces so powerful that their hearts won't be able to pump blood fast enough to their brains. The result: what physicians call g-induced loss of consciousness (GLOC). The Crew Technology Division at the Air Force's School of Aerospace Medicine (Brooks Air Force Base, Tex.) is now studying ways to prevent pilots from passing out in those situations. One approach is to develop better pressure suits. Other techniques attempt to fit the man to the machine. Since pilots who go through GLOC once seem to handle high g-forces better the second time, the group is trying to presensitize individuals by subjecting them to high g-forces in a centrifuge. Researchers are also seeking a drug that will, for short periods and without major side effects, elevate pilots' blood pressure enough to keep them conscious and in control as they undergo the peak g-forces created by ATF technology.

The overall aim of such research, according to W. Carter Alexander, chief of the Crew Technology Division, is to integrate the pilot and the plane so effectively that the ATF's cockpit systems will sense when the the pilot is incapacitated and temporarily take over the task of flying the plane. That capability will help the ATF approach the goal outlined by Air Force Secretary Edward C. Aldridge, Jr.—"to be both lethal and survivable against the threats and defenses projected for the late 1990s and beyond." □

Salvatore Salamone, a graduate student in MIT's Department of Earth, Atmospheric and Planetary Science, is an intern at HIGH TECHNOLOGY.

BIOMETRIC SECURITY: WHAT YOUR ARE, NOT WHAT YOU KNOW

Security-conscious corporations often find their security devices seriously lacking. Keys can be duplicated, identification badges can be forged, and personal identification numbers and combinations can be stolen. To overcome these problems, many companies are turning to "biometric" security systems that identify a person by his or her voice, fingerprint, hand geometry, or retinal pattern.

For example, La Reserve (White Plains, N.Y.), a luxury hotel, recently replaced the lock and key on the hotel's wine room with a fingerprint reader. "The key that gave access to $10,000–$20,000 worth of wines and champagne could be found anyplace at any given time," explains Margaret Schneider, the hotel's vice-president. "So for a rather low investment—about $2000—we went with biometrics."

The system La Reserve installed was the Ridge Reader from Fingermatrix (North White Plains, N.Y.), which identifies individuals by scanning a person's fingerprint and using proprietary algorithms to compare the configurations of specific points along the print's ridges with those stored in the system for that person. The only other major manufacturer of biometric fingerprint systems is Identix (Palo Alto, Cal.). Its IDX series does not depend on a group of discrete points for identification, but instead compares the patterns of complete fingerprints.

The yardstick by which all biometric systems are measured is the error rate. False negatives, called type I errors, are what prevent authorized users from gaining access because of an inaccurate reading of the biometric parameter. False positives, or type II errors, occur when an impostor gains access. It is generally not possible to have both the lowest type I and type II errors—they must be balanced. For example, if a system is designed to guard stringently against access by anyone whose biometric data fails to match perfectly with the stored system data, it will also reject a greater percentage of authorized people based on slight variations in their data.

Unfortunately, vendors as yet have no standards to ensure that they are using the same criteria to obtain accurate error-rate measurements. In part to generate such standards, a group of biometric system companies formed an industry trade association late last year. Located in Washington, D.C., the International Biometrics Association is developing standards in such areas as error-rate measurements and system interfaces, and is also disseminating information about the industry.

In the fingerprint system segment, the lowest type I error rate yet achieved is one in a thousand; type II errors have been reported as low as one in a million. While this appears to be fairly good protection, it may not be adequate for extreme security applications. In these situations, retinal scans are often considered. Like fingerprint patterns, the patterns of blood vessels at the back of the eye differ among individuals. The error rates for false positives and negatives in retinal scans, however, are both less than one in a million. EyeDentify (Beaverton, Ore.) attributes the difference to the fact that fingerprint readers can be affected by such factors as grease and abrasions, whereas the eye's condition remains essentially constant.

Companies are turning to systems that match voices, fingerprints, or retinal patterns to stop intruders.

EyeDentify holds a patent on retinal scan systems used for identification, and is currently the only manufacturer of such a system, which sells for $11,000. A marketing obstacle the company has had to face is that some potential users are reluctant to place their eye in the path of what they fear to be a laser. In fact, the scanning light source is a harmless infrared light-emitting diode. The system measures the reflected light to determine the pattern of the retinal vasculature.

Some users who do not require the most extreme security are opting for hand-geometry, voice-identification, or signature-verification systems. An advantage of these systems is that they neither carry the stigma of being fingerprinted nor generate the fear of eye damage.

Hand-geometry readers make identifications on the basis of finger length, palm dimensions, and skin translucency, with specific techniques varying among manufacturers. One of the most popular systems, the Identimat sold by Stellar Systems (Santa Clara, Cal.), reportedly achieves false positive and negative rates of 2.5%; the price is $8745 for a complete system.

The Stellar Systems error rate and price are both higher than other biometric systems, but Ben Miller, publisher of *Personal Identification News* (Washington, D.C.), an industry newsletter, notes that the company has been in business for more than 10 years and thus has a fairly high profile compared to some newer firms in the market. Nevertheless, he says, competitors are entering the hand-geometry field, "and they are starting to pull away some of Stellar's business by offering better error rates and lower prices." Two such firms are Recognition Systems (San Jose, Cal.), which markets a system called ID-3D, and Mitsubishi Electric Sales America (Cypress, Cal.), with its Palm Recognition System. Esselte Tech (Solna, Sweden) also plans to introduce a system in the U.S.

One reason for the increased competition is the perception among vendors that hand-geometry readers will be easily accepted by users: because people are used to shaking hands and putting their palms on door knobs, they will not object to placing their hands in a reader.

Another, relatively new biometric technology—voice identification, which requires a user to speak a few words into a telephone-like instrument—is also receiving increasing attention because of its perceived user acceptance. Currently, only two companies—Ecco Industries (Danvers, Mass.) and Voxtron Systems (New Braunfels, Tex.)—sell voice identifiers commercially. System costs average about $2500 per protected door; error rates are comparable to fingerprint readers.

Each vendor uses its own proprietary techniques to extract voice features for

by Sam Diamond

speaker identification. Ecco bases its system on a method called linear predictive coding (LPC), which attempts to characterize each speaker's vocal tract mathematically. "LPC is very speaker-dependent," says Ecco president Heath Paley, "because the geometry that produces a certain word for one person is not going to be the same as for another person." Voxtron, on the other hand, employs a technique that uses filter banks to extract and compare the frequency and pitch of each utterance. Either method can easily identify impostors, claims Paley, because people attempting to impersonate others' voices rely largely on duplicating the phrasing and intonation, which would be virtually ignored by the LPC and filter-bank algorithms.

The National Cooperative Bank (Washington, D.C.) was the first commercial user of Ecco's VoiceKey Access Control Security System. Dennis Opicka, the bank's corporate vice-president, believed that the card readers the bank previously used for controlling access to offices were not providing adequate security, and that the voice-identification system would be readily accepted. "It looks like a telephone, is not intimidating, and is simple to use," he says. An added advantage for the bank was the system's ability—common to many biometric systems—to maintain audit trails of all users automatically, without their having to enter personal identification numbers.

The only other biometric systems now available commercially are those that identify people by their signature dynamics—the speed with which they sign their name, the pressure used, and how they dot their i's and cross their t's—which are extremely difficult to forge. Their primary application so far is at point-of-sale terminals, where customers are already used to signing their names. Manufacturers include Confirma (Menlo Park, Cal.), Thomas De La Rue (Herndon, Va.), IBM's Information Products Division (Charlotte, N.C.), Inforite (San Mateo, Cal.), Signify (Baltimore, Md.), Ion Track Instruments (Burlington, Mass.), and TITN (Grenoble, France). Error rates range from below 1% for type I to over 3% for type II. This rate is far from negligible, but it is good enough to dissuade most thieves from trying to subvert the systems, which are almost always located in public places. System prices are generally below $1000.

Fingerprint scanners such as the Ridge Reader from Fingermatrix can achieve error rates as low as one in a million.

Even though the range of technologies is wide and growing wider, "all the biometric systems will find their own niches and will be developed to the point of filling the requirements of that niche," says Russ Maxwell, a staff member at Sandia National Laboratories (Albuquerque, N.M.), who runs a biometric systems evaluation program for the Department of Energy.

This process is already under way. Manufacturers of signature dynamics identification systems are targeting their products toward retail applications, while vendors of fingerprint readers are focusing on law enforcement. The primary area for retinal scanners seems to be the high-security government market, and voice identification is penetrating office environments where telephone communication is a way of life.

Even as these systems become refined and drop significantly in cost, new technologies can be expected to surface as developers work to find the most accurate or user-friendly methods for specific applications. Already, an identification system based on wrist vein patterns is being developed at the British Technology Group (London, England). Typing rhythms are being explored at Electronic Signature Lock (San Francisco), while hand topography is under study at Onset Venture (Palo Alto, Cal.). Still in the research stages at Battelle Columbus Laboratories (Columbus, Ohio) is a method that identifies the unique lipids and fatty acids found in skin oils extracted from forehead sweat.

Increased demand for biometric systems will develop as the needs for security intensify with growing dependence on the computer. Even now, vendors report that computer facilities account for approximately 50% of their sales. For example, On-Line Software International (Fort Lee, N.J.) recently announced that its Omniguard security package, designed to protect IBM mainframe environments, now supports Signify's Sign/On signature verification system. Other vendors are proposing systems that will limit access to personal computers.

In 1986, the U.S. market value of all biometric systems sold for computer security applications was projected to reach $4.4 million, according to a market survey prepared by the Business Communications Company (Stamford, Conn.). By 1991, the report predicts, the total value of all biometric systems sold for this purpose alone should increase to at least $24.2 million, for a total annualized average growth rate of 41%.

Several other application areas could also become important markets for biometric technology. Miller of *Personal Identification News* predicts that biometrics will complement another emerging technology, smart cards. These microprocessor-equipped credit cards house personal financial and identification data; in the wrong hands, they could result in the perpetration of much more serious fraud than is possible with conventional credit cards. To guard against such misuse, Miller suggests, smart cards will have to use biometric checking to verify the user's identity. Thanks to its on-board memory, the card itself can contain the user's biometric "print," which could be loaded into a security system for comparison with a reading taken directly from the user. □

Sam Diamond, a freelance writer based in Ridge, Long Island, N.Y., specializes in business and technology subjects.

COGENERATION: DUAL POWER CUTS COSTS

The combined production of electric and thermal energy using a single fuel source is emerging as an energy-conserving technology that not only helps manufacturers reduce costs but promises to provide relief from the electricity shortfalls that are expected during the next decade. Its principal users are processors like steel, aluminum, paper, food, chemical, and petrochemical companies.

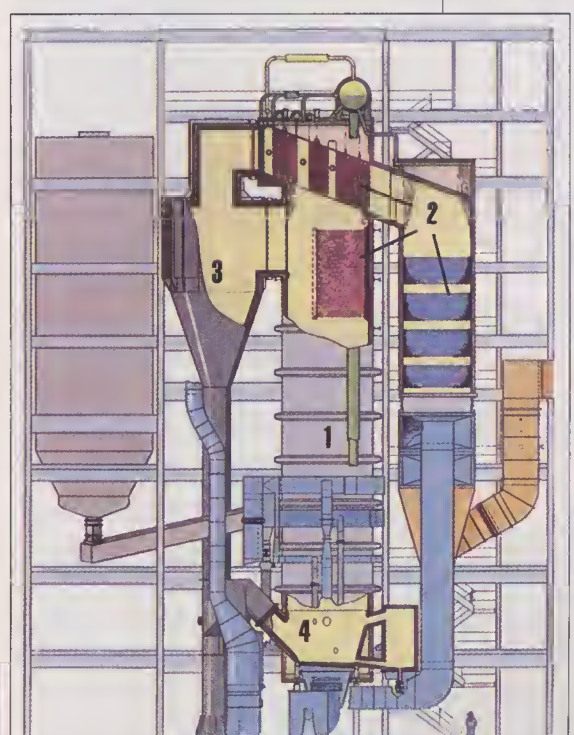
The concept, called cogeneration, is not new; it was used by major U.S. industries early this century when utilities could not respond to all their electrical needs. At one point more than 59% of the nation's electric generating capacity came from industry. Cogeneration began its reawakening with the energy crises of the 1970s and the resulting passage of the Public Utilities Regulatory Policy Act (PURPA) of 1978, which requires electric companies to pay competitive market rates for excess power produced by certified cogenerators. Thus in addition to supplying some of a manufacturer's electrical and thermal energy needs, cogeneration can be a modest source of revenue as well.

The growth of cogeneration since PURPA has been dramatic. In 1980, only 16 facilities filed with the Federal Energy Regulatory Commission to be certified as cogenerators. In 1985, there were 676 filings, and nearly 600 in the first three months of 1986.

Steam turbines are traditionally one of the principal cogeneration means because of their high reliability and efficiency. Fuels are burned in boilers, creating high-pressure steam that drives a turbine to generate electricity, and the waste heat can then be used as low-pressure steam for a wide range of industrial processes. Such arrangements are getting a boost from improvements in the economy and efficiency of boilers, particularly fluidized-bed combustion, which can burn such fuels as high-sulfur coal, petroleum coke, or industrial wastes (pulp from paper processing, for example), while keeping sulfur dioxide emissions to relatively low levels. Pressurized air is blown up through the floor of the combustion chamber, "floating" the fuel as the air mixes thoroughly with it. This reduces incomplete combustion, which plagues conventional boilers (where solid fuel is simply laid on the bed). To prevent sulfurous emissions, powdered limestone is included in the mixture; it reacts with sulfur dioxide to form calcium sulfate, an ash. Principal suppliers of fluidized-bed combustion boilers include Foster Wheeler Boiler (Livingston, N.J.), FluiDyne Engineering (Minneapolis, Minn.), Thermal-Transfer (Monroeville, Pa.), and York-Shipley (York, Pa.).

Pyropower (San Diego) is installing a circulating fluidized-bed combustion unit in Gilberton, Pa., that is fueled by anthracite culm, a low-thermal-value coal-mining waste that has accumulated in the region for nearly 100 years. This plant takes the combustion efficiency of fluidized-bed boilers a step farther by using a separator that filters unburned fuel and limestone particles from the hot flue gases as they exit the boiler; the particulates are then reinjected into the combustion chamber. Steam from the Gilberton boiler will turn a General Electric turbine, generating about 80 megawatts of electricity to be sold to Pennsylvania Power and Light, and steam will be used by an adjacent coal-drying facility.

In Pyropower's circulating fluidized-bed combustion boiler at GM's Fiero car plant in Pontiac, Mich., fuel is blown upward into the combustion chamber (1), where steam for cogeneration is made in a series of banks (2). Hot gases exit through the "hot cyclone" (3), shaped to create a swirling action that forces unburned particles downward to the loop seal (4), where they reenter the combustion chamber.



Also used in cogeneration, gas-turbine generators operate like jet airplane engines. A rotary compressor feeds pressurized air into a combustion chamber, where injected fuel is ignited. As they exit the engine, the expanding combustion gases force their way through a turbine, causing it to spin. In addition to providing the rotary power for its compressor, the spinning turbine is connected to an electrical generator. In cogeneration applications, exhaust gas is harnessed as process heat as it exits the engine.

Gas turbines can generate more electricity for a given amount of thermal energy (reserving less for processing needs), and are therefore preferred by many companies more concerned with producing electric power than heat. Another advantage is that plants can be operational in only about nine to fourteen months, compared to about one to three years for steam systems, which often require EPA certification and generally must be built on-site due to their larger size. Gas turbines, on the other hand, can often be shipped as "packaged" components that require less on-site construction.

Using turbines as cogenerators becomes tricky, however, if the company's demand for heat fluctuates. In a single-cycle configuration the turbine generates electricity at a constant rate, and when

by Jeffrey Seisler

process heat demand is low the excess can simply be vented, a costly and inefficient alternative. Or the cogenerator can reduce the speed of the turbine so that only the desired amount of exhaust heat is produced. This approach, however, not only reduces the amount of electricity but also lowers fuel efficiency and usually shortens the life of turbines, which operate best at constant rates.

One alternative is a dual-cycle cogeneration setup, requiring a separate steam turbine (such as that used with a boiler) powered by excess steam. A disadvantage is that the separate steam turbine is used only a portion of the time.

Another alternative is the Cheng cycle, a recent advance in steam turbines that is gaining popularity among cogenerators whose demand for process heat varies. International Power Technology (Palo Alto, Cal.), founded by the concept's developer, Dah Yu Cheng, supplies Cheng-cycle cogenerators that basically recirculate unused steam back into the turbine. The excess steam is superheated by passing it through the engine's exhaust stream and is then injected into the combustion chamber. The steam increases the density of the gases flowing across the turbine blades, basically giving more push to the burning fuel. This improves the efficiency of the turbine by up to 40%, says International Power. To prolong turbine life, Cheng units operate at a constant speed, which requires sophisticated balancing of fuel, air, and recycled steam, accomplished electronically by a Network 90 computerized controller supplied by Bailey Controls (Los Angeles).

Cheng-cycle cogenerators are gaining wide acceptance among food processors, which have seasonal variations in steam requirements. For example, Sunkist Growers uses one at its juice-concentrate facility in Ontario, Cal. Frito Lay and Hershey Chocolate likewise have California facilities that use Cheng-cycle cogenerators.

A promising, though still largely experimental, cogeneration technology is fuel cells—electrochemical devices that convert a fuel's chemical energy directly into electricity and heat with no intermediate combustion cycle. The process starts with a "reformer" that uses steam to convert the fuel (usually natural gas) into hydrogen and carbon dioxide. The hydrogen then goes to the fuel-cell stacks, where the splitting of hydrogen molecules (H_2) at each anode frees electrons, which then flow to the cathodes through an external

circuit. In cogeneration, heat released by the reactions occurring in the cells is collected for use in industrial processes.

Jeffrey Serfass, executive director of the Fuel Cell Users Group of the Electric Utility Industry trade association in Washington, D.C., explains that heat generated by fuel cells meets low- to mid-level heat requirements—from about 150° F to 250° F. So far, however, fuel cells have not been widely considered for cogeneration; instead, emphasis has been on commercializing the technology for mainline power-generating facilities (HIGH TECHNOLOGY, Dec. 1984, p. 52). Nevertheless, a program by the Gas Research Institute (Chicago) successfully demonstrated small, 40-kilowatt fuel-cell cogeneration units. And International Fuel Cells (South Windsor, Conn.) is developing 200-kilowatt units suitable for small industries.

Serfass, however, doesn't expect to see larger-capacity cogeneration until fuel cells are more widely used by the electric

Electric utilities encourage cogeneration in regions where they can't keep up with growth.

utility industry, possibly in the mid-1990s. Until then, he says, their cost and the risks involved will remain too high.

In some regions, industrial cogeneration facilities are being opposed by electric utilities that have sufficient generating capacity and therefore do not want to buy a cogenerator's excess power. "Capacity-rich companies," says Lee Mitterer, a regulatory analyst at the Edison Electric Institute, "are establishing electric rates to prevent the premature development of cogeneration systems." For example, both Arkansas Power & Light and Public Service of New Mexico have created Cogeneration Deferral Programs in which the rate is low enough to compete against cogeneration savings, and is made for a significant term—10 to 15 years—in order to be an attractive way for the customer to defer a capital-intensive investment in cogeneration.

However, in regions where utilities can't meet their current or projected demand for power, cogeneration is viewed as an opportunity to avoid the high costs of new generating facilities. Jersey Central Power & Light, for example, is faced

with a capacity shortage caused by the suspension of the Three Mile Island plant (which supplied JCP&L) and the cancellation of another nuclear facility. Thus, says Glen Steiger, manager of research and development, "we are looking at cogenerated power as an alternative to new power-plant construction." Currently, JCP&L must buy about half of its power from other utilities, but it has signed contracts with Newark Boxboard, which will run a 51-megawatt cogeneration facility, and Marcal Paper in Elmwood Park, which will build a 70-megawatt cogeneration plant. An additonal 300 megawatts from two other projects are also anticipated.

The rise in cogeneration is also engendering creative financial arrangements between industries and electric utilities. For example, Celanese Chemical in Pampa, Tex., burns pulverized, low-sulfur coal in two high-pressure boilers, creating steam that turns a 30-megawatt generator and is then reused in chemical processes. Celanese shares ownership of the cogeneration facility with the utility Southwestern Public Service; Southwestern owns the turbine and sells power to Celanese; the chemical company owns the boilers and sells steam to the utility.

A big advantage of cogeneration is that it can serve as an auxiliary electricity source to supplement potential power shortfalls anticipated in the 1990s. According to the North American Electric Reliability Council, by mid-1990s electric generation capacity in the U.S. will be at a minimum acceptable level, and the electric utility industry will enter 1995 with more than 100,000 megawatts of generating equipment that is 30 years old. Because of environmental considerations, regulatory issues, and costs associated with developing large-scale nuclear and coal-fired plants, U.S. utilities have no new construction scheduled, says executive consultant Robert M. Grant of Stone & Webster Management Consultants (New York), although a number of current projects are near completion. Instead, the trend is to extend the lifetime of existing facilities through maintenance and repair. "But you can only patch for so long," says Grant.

While this trend favors cogeneration, Grant says this is only a partial solution to the expected shortfall: "It would take too much cogeneration capacity." Nevertheless, he says, cogeneration will continue to grow, primarily because cost-conscious manufacturers and processors are pushing it. A recent Department of Energy report, for instance, says current industry has the potential to cogenerate 39,000 megawatts, while projected industrial growth to the year 2000 could add another 47,000 megawatts. □

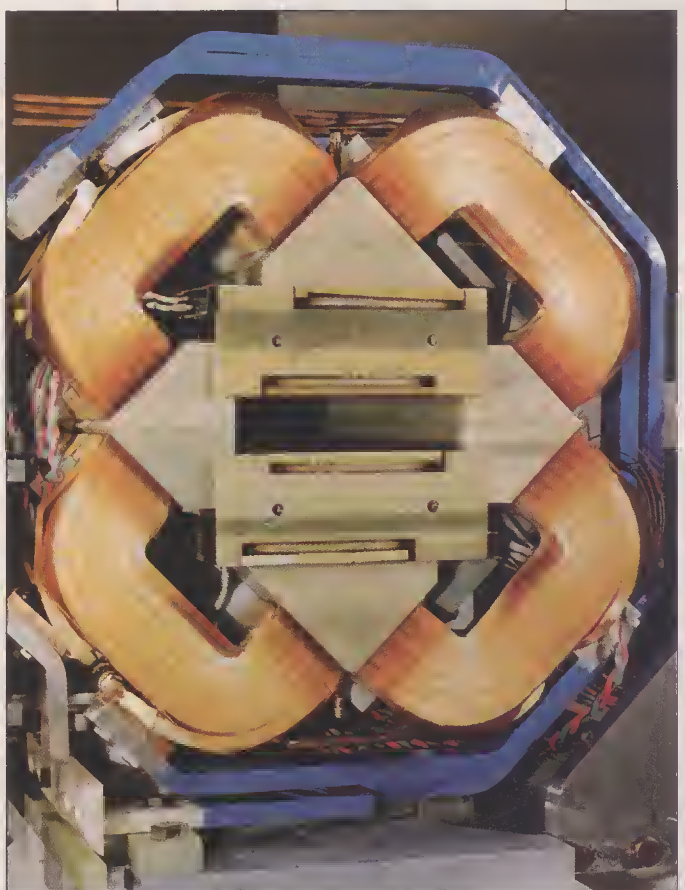
Jeffrey Seisler, manager of natural gas vehicle market development for the American Gas Association, is an energy analyst and freelance writer.

LASER-LAUNCHED ROCKETS MAY ORBIT SMALL PAYLOADS

By the early 1990s, it may be possible to launch small experimental payloads into orbit, at very low cost, on rockets driven by ground-based lasers and consisting of little more than blocks of plastic or ice. The concept has attracted several aerospace companies and engineering firms into a tentative $2 million program run by the Strategic Defense Initiative Organization (SDIO). The propulsion technique is a spinoff of the organization's ground-based laser-defense program, in which enemy missiles would be destroyed by a laser beam directed into the atmosphere and bounced from orbiting mirrors.

Laser-driven rockets would rely on a new device called the free-electron laser (FEL), which is more powerful and more efficient than conventional chemical lasers. In the FEL, a linear accelerator (linac) is used to produce a high-energy beam passed through a "wiggler"—an array of magnets that expose the beam alternately to north and south magnetic poles. As the electrons oscillate in the wiggler, they release laser light in wavelengths ranging from the visible to the infrared, depending on the beam's energy. With a wiggler of appropriate design, the efficiency may approach 40%, according to studies at California's Lawrence Livermore National Laboratory, compared with 5% for a typical chemical laser.

Conceived in 1972 by Arthur Kantrowitz, then president of Avco-Textron (Everett, Mass.), the method would provide thrust to a rocket by laser-blasting thin layers of material from a block of material rich in hydrogen, the element that gives the greatest exhaust velocity. The rocket would consist basically of a payload—such as equipment for orbiting power stations—resting on the block. Given the number of hydrogen-containing compounds, the range of possible propellants is astonishingly wide; plastics or coal, for example, could be used, with ice regarded as a benchmark for comparison. In one mechanism, proposed by Avco-Textron engineer Dennis Reilly, the pulses would occur in closely spaced pairs: the first, relatively weak pulse would vaporize a small amount of material to form a film of hydrogen over the bottom face of the block. The more powerful second pulse would provide thrust by imparting energy to the film and causing it to expand rapidly. In this way, the exhaust



A magnetic "wiggler" may be used to convert the energy of accelerated electrons into efficient ground-based laser beams.

would reach much higher temperatures and velocities than with conventional liquid or solid chemical propellants. Recent studies suggest that as a result of its high exhaust velocities, a laser-driven rocket could deliver some 15% of its lift-off weight into orbit as payload, versus the Space Shuttle's 1½%.

The FEL program is being directed by the Army's Strategic Defense Command, which is now designing a large test site to be built at White Sands, N.M., during the early 1990s. Initial efforts will focus on computer modeling and experiments with existing lasers; meanwhile, researchers will study how lasers transfer energy into a thrust-producing blast wave. Because of the linacs, the lasers would be hundreds of meters long; thus the project involves engineer-architects as well as laser specialists. One study group, headed by TRW, includes Lockheed Missiles & Space (Sunnyvale, Cal.) for lasers and the Ralph M. Parson Co. (Pasadena, Cal.) for engineering and architecture; another group is headed by Boeing (Seattle), and includes Hughes Aircraft (Los Angeles) and Bechtel (San Francisco).

Meanwhile, SDIO scientists will attempt to develop methods for controlling laser-propelled rockets in flight. For example, ground controllers might tilt the rocket by moving the laser beam off-center. Another control mechanism is to aim the laser at the block at an angle, rather than from directly below; the orientation of the block will thus determine the direction of the exhaust and its thrust.

The cost of electricity for the launch is estimated at about $18 per kilogram of payload; even amortizing the cost of the laser would raise the tab to only about $100 per kilogram. (By contrast, power costs for the Shuttle run about $10,000 per kilogram.) If its laser ran more or less constantly, such a launcher could lift 64,000 tons of payload per year. An infrastructure would have to be established for the low-cost and continuous launch of payloads of a ton or so for such a system to be of optimum value.

Initial test flights of small tethered craft are scheduled for 1991–92. □

—T. A. Heppenheimer

MAGNETIC RESONANCE ANALYZES BODY CHEMISTRY

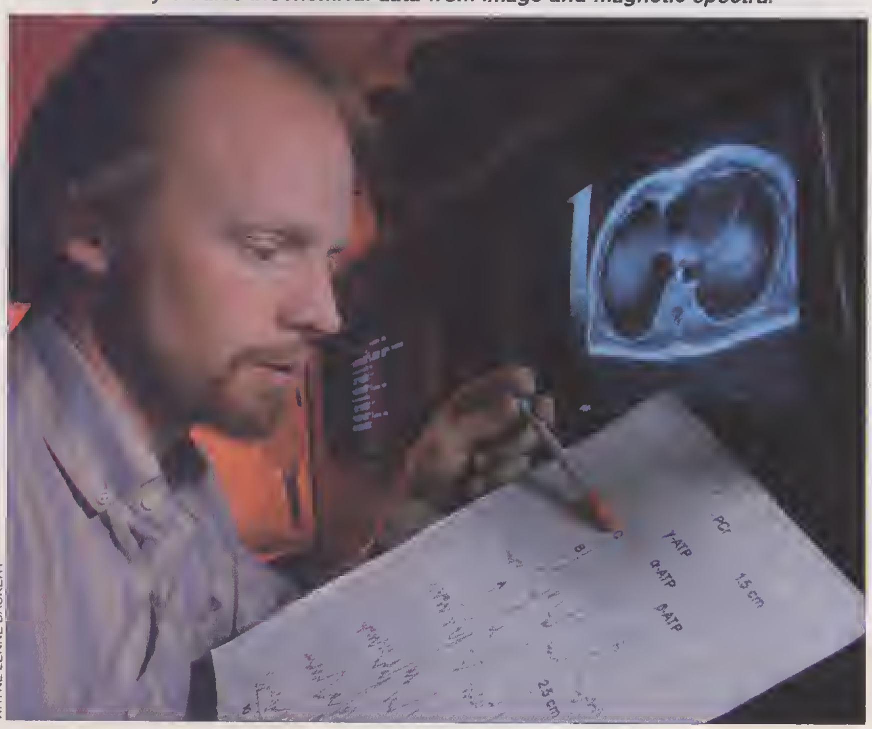
During the past few years, magnetic resonance imaging (MRI) has become a widely accepted diagnostic tool for physicians. By subjecting a patient's body to strong magnetic fields, the presence of certain chemical elements, notably hydrogen, which indicates water in body tissue, can be imaged. Unlike computerized tomography (CT), MRI readily distinguishes different materials in the body—bone, muscle, fat—without x-rays or dye injections.

In order to examine a wider range of chemical elements than can normally be imaged with MRI, and determine the amount of chemicals present in parts of the body, researchers are turning to a complementary technique—magnetic resonance spectroscopy (MRS)—that may render MRI an even more powerful diagnostic tool. MRS does not produce images, but it generates spectra that show the distribution of an element within the body. The technique would allow researchers and physicians to examine such elements as phosphorus, lithium, sodium, potassium, fluorine, and carbon, whose properties aid in diagnosing heart disease and cancer.

Research at the General Electric Research and Development Center (Schenectady, N.Y.) under Paul Bottomley has led to the development of a whole-body imaging and spectroscopy research system. A similar system has been built at MIT. Bottomley has also pioneered a technique called depth-resolved surface coil spectroscopy (DRESS), which uses a magnetic field that varies with depth of penetration into the body to obtain localized spectra that can be coupled with anatomic information from imaging.

Bottomley's best results so far have occurred in phosphorus spectroscopy of the heart. Spectra obtained in minutes can help determine whether a patient's symptoms indicate a heart attack or a minor ailment. Similar examinations of the brain could diagnose possible stroke victims, says Bottomley, as well as provide new information about such neurological disorders as Parkinson's disease or Alzheimer's disease, in which high phosphorus levels have been recorded in postmortem brain spectra.

GE's Bottomley studies biochemical data from image and magnetic spectra.



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GE's Medical Systems Group (Milwaukee, Wis.) has already marketed a combined imaging and spectroscopy system. The combination "provides information previously available only through time-consuming tissue biopsy," according to Cecil Charles, manager of the company's spectroscopy project.

While phosphorus and hydrogen are easy to detect magnetically because their abundance yields large magnetic resonance signals, lesser elements that may provide valuable data can also be detected by MRS. For example, small amounts of carbon-13 naturally present in the body can be detected in blood sugars. Using MRS, Robert Shulman of Yale University has been studying physiological control by monitoring sugars and related chemicals in animals.

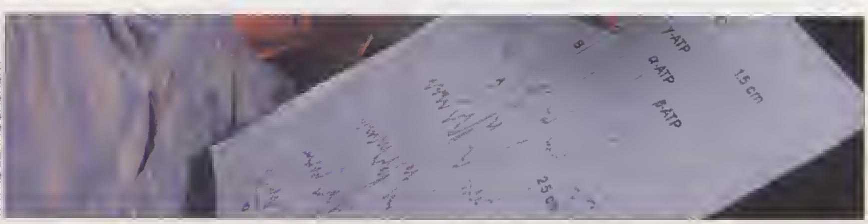
The most powerful diagnostic tool may be one that can monitor several elements simultaneously. Such a system, although still experimental, has entered routine clinical use at the University of Texas Health Science Center (Dallas). It uses two Digital Equipment VAX computers and two superminicomputers developed for medical uses by Masscomp (Westford, Mass.) to record the spectra of up to four different chemicals. "We want to track several nuclei in one experiment," says the system's designer, J. Thomas Vaughan, "instead of having to reset the equipment for each nucleus." The Texas researchers hope to monitor as many as eight nuclei, and are currently looking for a manufacturer. □ **—*Hugh Aldersey-Williams***

PASSING THE WORD ON TOXIC CHEMICALS

A growing variety of new computerized information tools are helping U.S. chemical producers cope with one of the most costly and far-reaching regulations to hit the industry in years: the Hazard Communications Standard, implemented last spring by the Occupational Safety and Health Administration (OSHA). The standard—which affects every chemical producer, importer, wholesaler, and warehouse operator—aims to reduce occupational accidents and illnesses in the chemical industry by requiring companies to distribute safety information for hazardous chemicals used or stored on site. The methods of distribu-

Charges typically consist of a subscription fee, an hourly database charge, a fee for information printed or displayed, and associated telecommunication costs.

One example is the Flow Gemini Occupational Health and Environmental Information System from Flow General (McLean, Va.), which consists of a library



WAYNE LENNE BACKERY

tration (OSHA). The standard—which affects every chemical producer, importer, wholesaler, and warehouse operator—aims to reduce occupational accidents and illnesses in the chemical industry by requiring companies to distribute safety information for hazardous chemicals used or stored on site. The methods of distribu-

tion include warning labels, worker training programs, and material safety data sheets, or MSDSs, which contain detailed information on a chemical's toxicity and are used in the prevention and treatment of exposure.

As a result, all but the smallest chemical companies are faced with gathering, collating, and distributing a staggering volume of safety data on hundreds of thousands of chemicals. Philadelphia chemical maker Rohm & Haas, for example, issues a complete updated set of its roughly 6700 product MSDSs every month.

One problem is that U.S. producers lack a single chemical-safety database that includes information on every OSHA-regulated chemical—and there's no indication that any such resource is being developed, by OSHA or anyone else. A comprehensive database "would save the industry a tremendous amount of money," says Raymond Gaydash, manager of planning information services at Mobay Chemical in Pittsburgh. As an ideal model of such a database, Gaydash points to the CCINFO program provided by the Canadian Centre for Occupational Health and Safety (Hamilton, Ontario). CCINFO is unavailable to U.S. producers, however, except those with Canadian affiliates. Most American companies must gather the data in bits and pieces from a variety of public and private sources.

One important (albeit incomplete) database is available from the government itself: the Registry of Toxic Effects of Chemical Substances, developed by the National Institute for Occupational Safety and Health in Cincinnati, contains toxicity data on some 75,000 chemicals. It is available through the National Library of Medicine's on-line MEDLARS service.

Private software vendors have responded with toxic-substance databases as well, many of which can also be used for such auxiliary purposes as training employees and preparing reports. The databases are accessed via appropriate ASCII terminal hardware equipped with a modem and communications software. Charges typically consist of a subscription fee, an hourly database charge, a fee for information printed or displayed, and associated telecommunication costs.

One example is the Flow Gemini Occupational Health and Environmental Information System from Flow General (McLean, Va.), which consists of a library of 16,000 MSDSs; it can be either mounted on a user's own mainframe or minicomputer or accessed on a timesharing basis on Flow General's computer. The system can also be used to perform statistical analysis, produce medical safety reports, and track down other MSDSs in use. The system is costly, however: a license for a system used with a MicroVAX II costs about $125,000, while the IBM or VAX 8600

mainframe user will pay about $260,000.

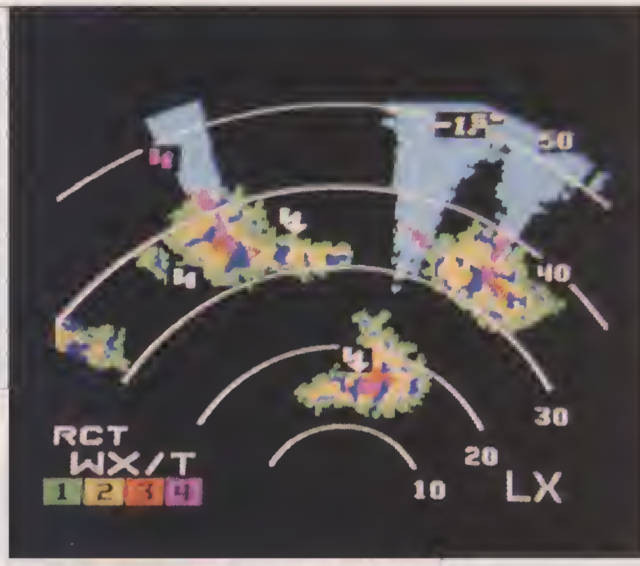
Several software packages are more moderately priced, ranging from about $500 to $2000. Clough Management Services (Rouse's Point, N.Y.), for example, offers MSDS Miti-Fix—a program for creating and organizing MSDSs in OSHA-approved form. Similar packages are available from Azimuth Technologies (Pasadena, Cal.), Genium Publishing (Schenectady, N.Y.), NUS Corp. (Pittsburgh), and OSHA-Soft (Concord, Mass.); programs from the latter two suppliers also contain modules for generating safety manuals and other employee training aids. And a management software package from Software Design in Mansfield, Mass., also includes text and graphics capabilities for the design and printing of warning labels.

Several companies have recently introduced optical storage systems for managing the vast amounts of data. For example, Poisindex (intended mainly for the treatment of poisoning) is available from Micromedex (Denver) in a CD-ROM format; the discs, updated every 90 days, provide information on more than 450,000 toxic and nontoxic substances. SilverPlatter Information (Wellesley, Mass.) also offers a number of CD-ROM databases applicable to hazard communications. One example is OSH-ROM, which combines three major health and safety databases with hundreds of toxic-substance records. □ *—Paul Hurly*

HELPING PILOTS STEER CLEAR OF STORMS

Every day, some 44,000 thunderstorms occur around the globe, disrupting power transmissions, communications, and transportation, particularly air travel. Sometimes towering more than 60,000 feet above the earth, these storms, often undetectable by conventional radars, can release their violence without warning. But with recent developments in lightning detection, commercial and private pilots can now determine the presence of thunderstorms and take appropriate evasive action.

Ordinary weather radar detects only visible moisture (as opposed to moisture in crystallized form) such as rain, wet hail, or wet snow. The more violent aspects of a thunderstorm—severe turbulence, strong downdrafts, abrupt wind shear, and microbursts—are not visible on weather radars because they do not produce radar reflections. Similarly, Doppler radar, which can detect rapid raindrop movement, is of little use in detecting thunderstorms that begin without wet precipitation—often the period of heaviest turbulence.



3M's Stormscope aids pilots in avoiding lightning, displayed as small dots.

The presence of lightning, however, is a definitive indicator of a thunderstorm. A lightning detection system can complement weather radar by providing reliable information on dynamic weather hazards. The first such detector was developed in 1976 by Paul Ryan, a Columbus, Ohio, engineer and private pilot who, when flying his own plane, had almost been killed by unanticipated thunderstorm turbulence.

Based on his observation that lightning discharges emitted sufficient electromagnetic radiation to be sensed on a low-frequency (50-kHz) radio receiver, Ryan developed the Stormscope, which measures the electromagnetic signals from lightning strikes and determines their bearing and range. The electrical discharges appear as small dots in their relative positions on a circular display. The Stormscope is now marketed by Aviation Safety Systems, a divison of 3M (Columbus, Ohio), which purchased the rights to Ryan's device in 1980. At less than $4000 for the simplest model, the Stormscope is available to private pilots who may not possess weather radars.

Two years ago, Sperry's Aerospace and Marine Group (Phoenix), now a division of Honeywell, joined efforts with 3M to supply the interface technology needed to overlay Stormscope information on Sperry's conventional weather-radar display. The result is a more complete picture of severe weather than either radar or the Stormscope can provide.

About the same time that Ryan was working on the Stormscope, Ernest Coleman, a former Navy electronics engineer, developed a system that could analyze lightning strokes in greater detail. By using a wider-bandwidth receiver, Coleman was able to distinguish the unique electrical signature of the most powerful, vertical lightning strokes. The large vertical strokes, caused by a wide separation of charges, are prime indicators of turbulence. Coleman found that what appears to be a single lightning bolt is actually a complex series of discharges of variable intensity. The Stormscope might easily mistake these variations as individual strokes spread over a wide range. By identifying the stronger vertical strokes, Coleman's method more accurately pinpoints lightning strokes and their range.

Coleman sold his patents to Sperry, which recently introduced a commercial lightning sensor system based on his technique. The Sperry sensor counts the number of lightning strokes in any seven-mile radius over a four-minute period. Symbols indicating three distinct activity levels are mapped on a radar display along with conventional radar-generated weather data. Thunderstorms as far as 200 miles away can be detected and traced even while a plane is on the ground, because the low-frequency lightning sensor, unlike radar, is not limited to line-of-sight reception. Because this system, unlike the Stormscope, works directly with radar weather systems, it is mainly intended for use with commercial aircraft, where precise detection and definition of thunderstorm activity is needed. □ *—Mark Patiky*

RESOURCES

Information sources for topics covered in our feature articles

PARALLEL COMPUTERS DIVERGE, P. 16

Companies

Alliant Computer Systems, 1 Monarch Dr., Littleton, MA 01460, (617) 486–4950.

Ametek, 610 N. Santa Anita Ave., Arcadia, CA 91006, (818) 445–6811.

BBN Advanced Computers, 10 Fawcett St., Cambridge, MA 02238, (617) 497–3700.

Concurrent Computer, 197 Hance Ave., Tinton Falls, NJ 07724, (201) 758–7000.

Convex Computer, 701 N. Plano Rd., Richardson, TX 75081, (214) 952–0200.

Cray Research, 608 Second Ave. S., Minneapolis, MN 55402, (612) 333–5889.

Culler Scientific, 100 Burns Pl., Santa Barbara, CA 93117, (805) 683–5631.

Elxsi, 2334 Lundy Pl., San Jose, CA 95131, (408) 942–0900.

Encore Computer, 257 Cedar Hill St., Marlborough, MA 01752, (617) 460–0500.

Fifth Generation Computer, 300 Park Ave., New York, NY 10022, (212) 308–0862.

Flexible Computer, P.O. Box 299005, Dallas, TX 75229-9005, (214) 929–6000.

Floating Point Systems, P.O. Box 23489, Portland, OR 97223, (503) 641–3151.

Goodyear Aerospace, 1210 Massillon Rd., Akron, OH 44315, (216) 796–3631.

Intel Scientific Computers, 15201 NW Greenbrier Pkwy., Beaverton, OR 97006, (503) 629–7629.

Loral Instrumentation, 8401 Aero Dr., San Diego, CA 92123, (619) 560–5888.

Masscomp, One Technology Park, Westford, MA 01886, (617) 692–6200.

NCube, 1815 NW 169th Pl., Suite 2030, Beaverton, OR 97006, (503) 629–5088.

Sequent, 15450 SW Koll Pkwy., Beaverton, OR 97006, (503) 626–5700.

Thinking Machines, 245 First St., Cambridge, MA 02142, (617) 876–1111.

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CIM, P. 28

Contact

Society of Manufacturing Engineers (SME), One SME Dr., P.O. Box 930, Dearborn, MI 48121, (416) 747–4017.

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ENERGY-WISE BUILDINGS, P. 36

Contacts

American Council for an Energy-Efficient Economy, 1001 Conn. Ave., NW, Suite 535, Wash., DC 20036, (202) 429–8873.

Energy Conservation Coalition, 1001 Conn. Ave., NW, Wash., DC 20036, (202) 466–5045.

International Thermal Storage Advisory Council, Suite 401, 5252 Balboa Ave., San Diego, CA 92117, (619) 560–4878.

Alliance to Save Energy, 1925 K St., NW, #206, Wash., DC 20006, (202) 857–0666.

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Contacts

Optical Society of America (OSA), 1816 Jefferson Pl., NW, Wash., DC 20036, (202) 223–8130.

SPIE—The International Society for Optical Engineering, P.O. Box 10, 1022 19th St., Bellingham, WA 98227, (206) 676–3290.

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Financing: $13 million from investors including Capital Management, Arthur Rock & Co., Hambrecht & Quist, Asset Management, John Hancock Venture Capital, Arthur D. Little, Vanguard Associates, Walden, New Zealand Insurance, and USWest.

Management: Sheldon Breiner (cofounder and president) was founder and president of GeoMetrics, Peter E. Hart (cofounder and VP of research and development) was founder and director of Schlumberger's AI laboratory and director of SRI International's AI center; George J. Turner (VP of operations) was manager of corporate decision systems at Weyerhauser.

Location: 1000 Hamlin Court, Sunnyvale, CA 94088, (408) 745–6666.

Founded: March 1983.

APPLIED BIOTECHNOLOGY:

From cancer drugs to animal vaccines

Unlike some biotechnology companies that are strictly R&D-oriented and work on a contractual basis, Applied bioTechnology (AbT) has established partnerships with two major players to develop products in the veterinary and human healthcare markets. In a joint venture called Oncogenetic Partners, Du Pont (Wilmington, Del.) and AbT will concentrate on products for the diagnosis and treatment of cancer. AbT and the Battelle Memorial Institute (Columbus, Ohio) will create vaccines for diseases of poultry.

Applied bioTechnology's Dennis Panicali developed a novel method for designing new vaccines.

Using recombinant DNA techniques, AbT has produced two types of vaccines. One is based on live, genetically engineered viruses and subunit vaccines, in which noninfectious particles found on the surface of the virus often elicit an immune response against the live organism. The other is made using a proprietary technology called CRESP (Coding Region Expression Selection Plasmid), which identifies the viral genes responsible for the noninfectious particles and thus allows researchers to manufacture the particles themselves. AbT's major efforts in vaccine development thus far include vaccines against canine parvovirus and against pseudorabies virus of swine (a highly contagious and often fatal disease that also infects cattle and sheep).

Financing: $5 million from investors including Prutec, Investors in Industry, Robert Fleming Management, St. James's Venture Capital Fund, Loeb Partners Corp., and Euclid Partnership Corp. A $110,550 grant for the development of cancer diagnostic products based on DNA probe technology with Mass. Medical Center from Massachusetts Centers of Excellence Corporation.

Management: Steven M. Peltzman (president and CEO) was director of Millipore's Medical Products Division, Dennis L. Panicali (director of vaccine R&D) was a research scientist in the New York State Department of Health's Center for Laboratories and Research, and Bryan E. Roberts (director of long-term vaccine research and one of the six university professors who founded the company) is an associate professor of biological chemistry at Harvard Medical School.

Location: 80 Rogers St., Cambridge, MA 02142, (617) 492–7289.

Founded: September 1984.

CYDROME:

Ultrafast computers for technical users

Not every company can afford to buy a supercomputer. And supercomputer timesharing is an inconvenience for scientists and engineers who require a fast turnaround of data. An alternative is minisupercomputers, which help fill the gap between supercomputers and superminicomputers such as the DEC MicroVAX.

Cydrome's minisupercomputer uses the Unix System V operating system and an intelligent Fortran compiler that reportedly organizes the parallel structures within a software program. A single numeric processor performs multiple functions in parallel, and several Motorola 68020 microprocessors do general processing such as program editing and compilation. Cydrome's minisupercomputer, scheduled for release in mid-1987, will be marketed for users in applications such as structural analysis, semiconductor and mechanical design, and computer simulation.

Financing: $19.6 million from investors including Asset Management, Institutional Venture Partners, U.S. Venture Partners, Bryan & Edwards, General Electric Venture Capital Corp., MRI Ventures, Nazem & Company, OSCCO, Prime Computer, Security Pacific Capital Corp., Stanford University Engineering Fund, UNC Ventures, Walden Ventures, and Abingworth.

Management: André O. Schwager (president and CEO) was formerly vice-president of Dataquest and general manager of Hewlett-Packard's Information Networks Division; B. Ramakrishna Rau (vice-president of engineering and chief scientist) was manager of hardware development at ELXSI, a manufacturer of multinodal 64-bit computers; and William D. Walton (vice-president of hardware) was group manager for Digital Equipment's VAX 8600 system.

Location: 1589 Centre Pointe Dr., Milpitas, CA 95035, (408) 943–9460.

Founded: May 1984

—Margaret Woisard

INVESTMENTS

SYSTEMS INTEGRATORS TAP GROWING GOVERNMENT BUSINESS

In the past few years, government agencies have increasingly turned to systems integration firms—rather than hardware manufacturers—for linking computers, software, and communications systems into very large, integrated networks. These firms serve as one-stop shopping centers, with responsiblity for the design, purchase, installation, and training for such systems. Government agencies in particular have been using these third parties; since 1982, some 15 government contracts for large-scale projects, worth $3.2 billion, have been awarded. During 1987–88, the total value of such contracts is expected to reach almost $10 billion, according to Merrill Lynch (New York).

Several recent contracts indicate the size and scope of the programs involved. The Patent and Trademark Office, for example, has awarded a $289 million contract to Planning Research Corp. (PRC) for an automated record-keeping system. The U.S. Naval Intelligence Command has signed on Systems Development Corp. for a $150 million contract that involves ocean surveillance and message-processing systems. And Systems Development, Rockwell International, and Bendix Field Engineering are coordinating a $685 million contract for NASA services.

Two leading public companies in this field are Electronic Data Systems (Dallas) and Computer Sciences (El Segundo, Cal.). PRC (recently acquired by Emhart), Martin Marietta, SHL Systemhouse, and BDM International are other major competitors, along with several computer vendors themselves, including IBM's Federal Systems Division and Systems Development Corp., a subsidiary of Unisys (the company formed from the merger of Burroughs and Sperry).

Based on its extensive experience with data services and computer facilities management, **Electronic Data Systems** (NYSE: GME) has been the dominant player in government systems integration since winning a $656 million contract in 1982 for installing new mainframes at 49 domestic bases of the U.S. Army, linking this equipment to six regional data centers, and providing database management software and training. Among more recent contracts are those from the Department of Agriculture (worth $223 million) for installing and integrating some 16,000 AT&T minicomputers and personal computers at about 5000 Soil Conservation Service and Farmers Home Administration offices, and from the Air Force ($115 million) for a system to identify and track munitions at all U.S. bases.

EDS was purchased by General Motors in 1984, but investors may still participate in EDS dividends through the Class E stock that GM issued at the time of acquisition. EDS's revenues were $3.4 billion in 1985, with profits of $191 million and $1.57 earnings per share. Estimated 1986 revenues are $4.3 billion ($500 million of which should come from government work, $600 million from corporate data services, and the remainder from GM functions), with profits advancing to $262 million and earnings per share to $2.15. The company's dependence on GM's capital spending plans, unresolved questions about EDS profits under long-term contracts with GM, and the resignation of founder H. Ross Perot as EDS chairman have added some uncertainty for investors. Long-range prospects for EDS, however, appear favorable; EDS continues to do substantial business in its traditional areas of strength and is now in a good position to apply systems integration services to Fortune 500 firms other than GM.

Computer Sciences is building a data communications network linking U.S. Customs Service terminals at airports and border checkpoints with the agency's law-enforcement and import-export records.

Computer Sciences (NYSE: CSC) provides custom software and communications services to the Federal government—accounting for some 80% of the firm's business—as well as to the insurance and consumer credit industries, among others. After a slow start in the government systems integration market, CSC has won five contracts since mid-1985. They include a $282 million award to develop a data network for the U.S. Treasury Department's Customs Service, an office automation contract for at least $186 million to integrate 13,000 workstations and several thousand peripherals at Air Force bases and laboratories, and a $110 million Air Force contract to facilitate control and distribution of spare parts. CSC's investment prospects appear very favorable, as the firm is in a good position to win a portion of the $5 billion in government contracts it is pursuing. Moreover, CSC recently bought Computer Partners and several other commercial data service firms to help extend its business in nongovernmental sectors.

Revenues should climb from $839 million in 1985 to over $1 billion in 1986. Profits in these two years should also increase from $25 million to $32 million, with earnings per share climbing from $1.61 to $2.05. □

by Stephen T. McClellan

Stephen T. McClellan is a vice-president at Merrill Lynch (New York), where he covers the computer data service and software industries.

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